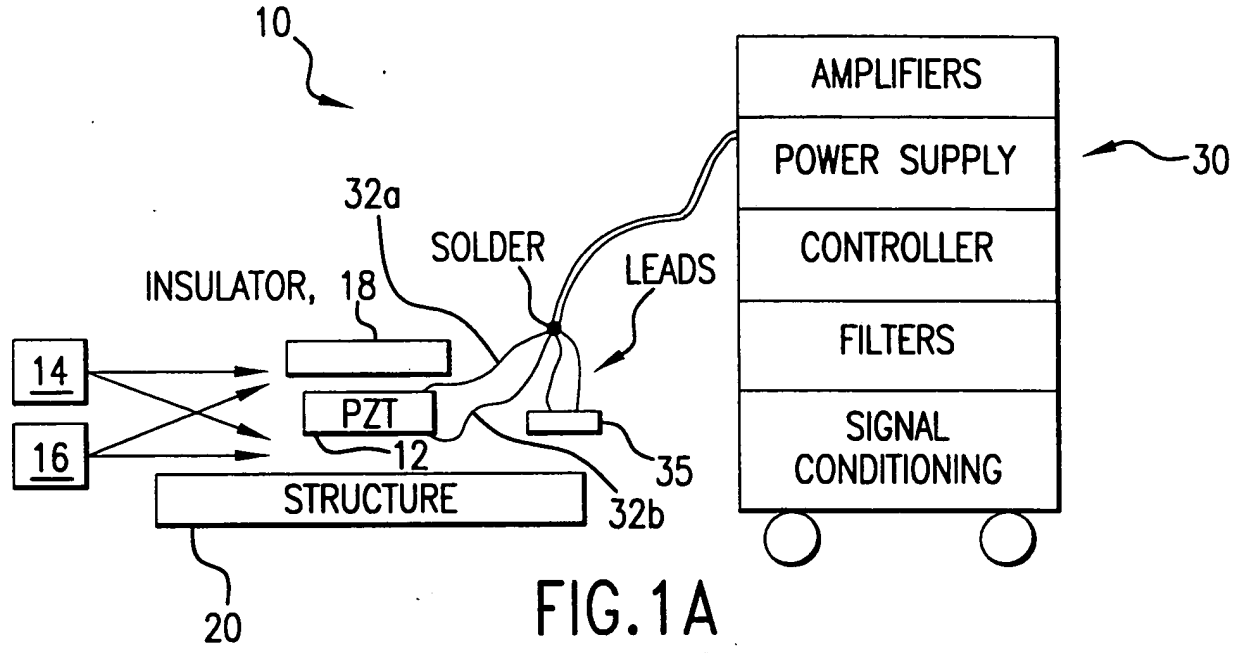


FIG.1A
PRIOR ART

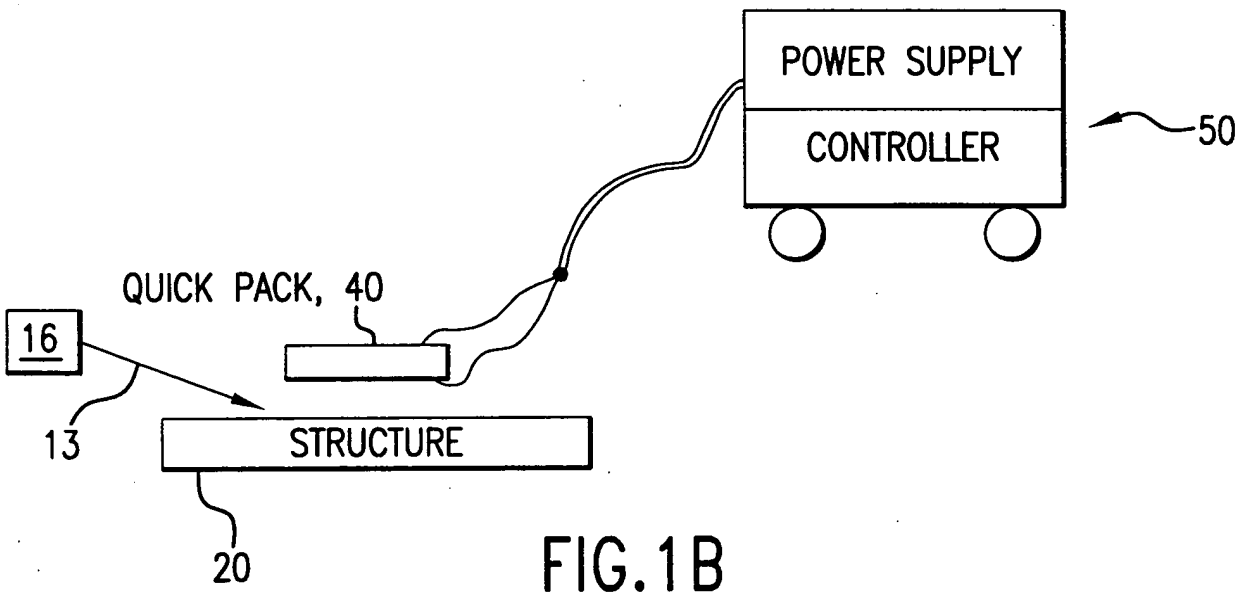


FIG.1B

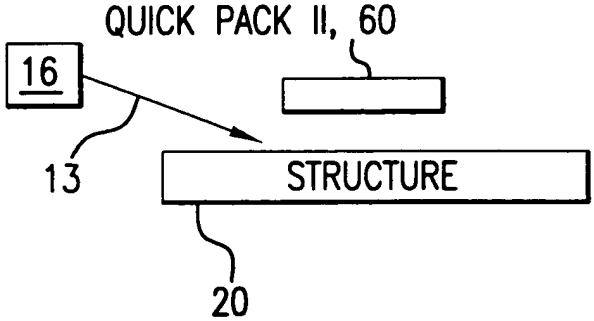


FIG.1C

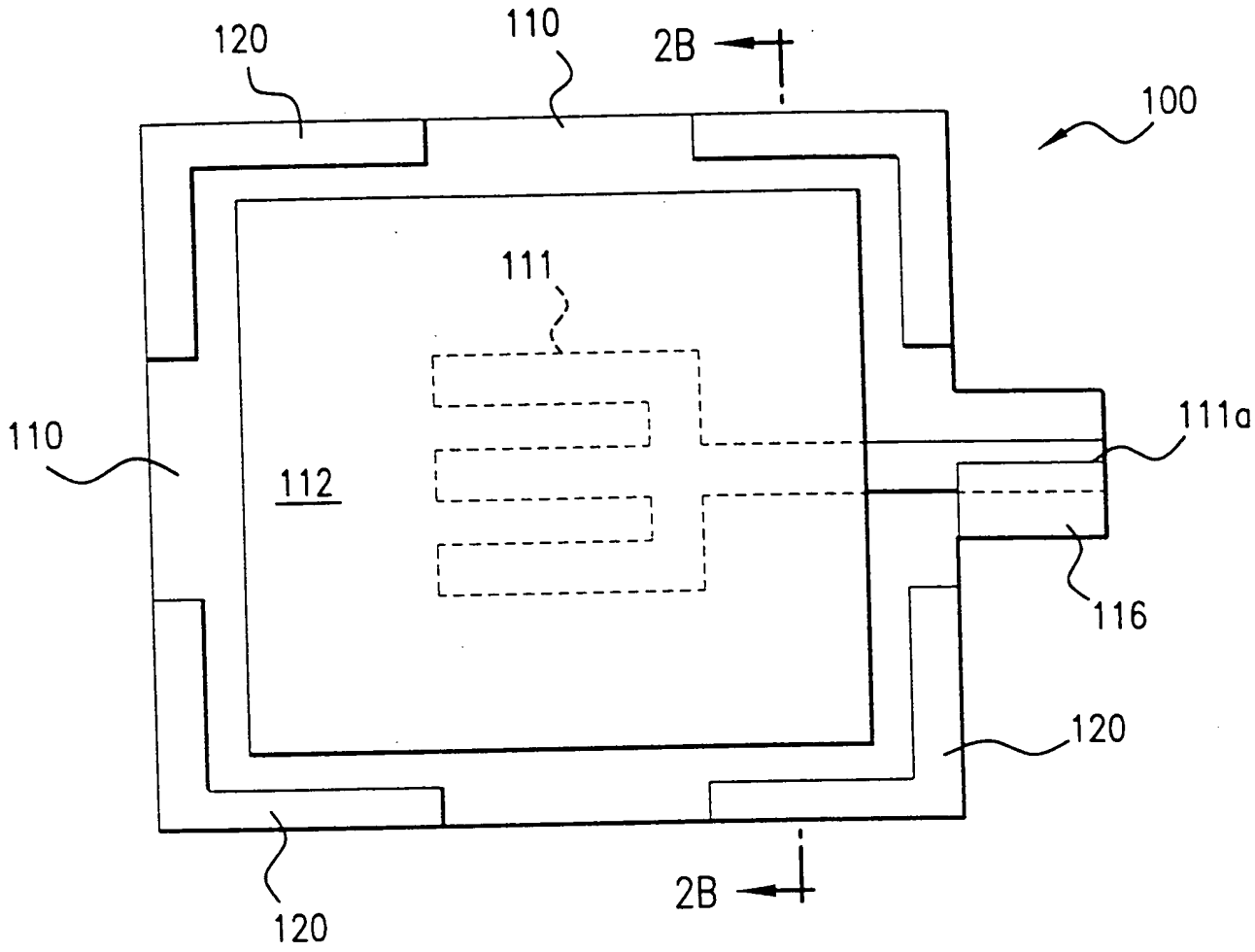

120
110
2B
100
111
110
112
111a
116
120
120
2B

FIG.2A

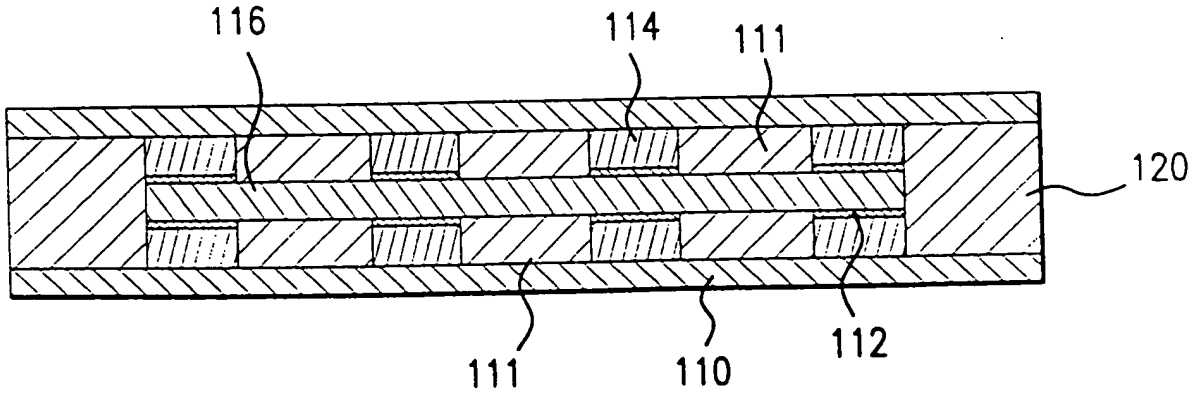

116
114
111
120
111
110
112

FIG.2B

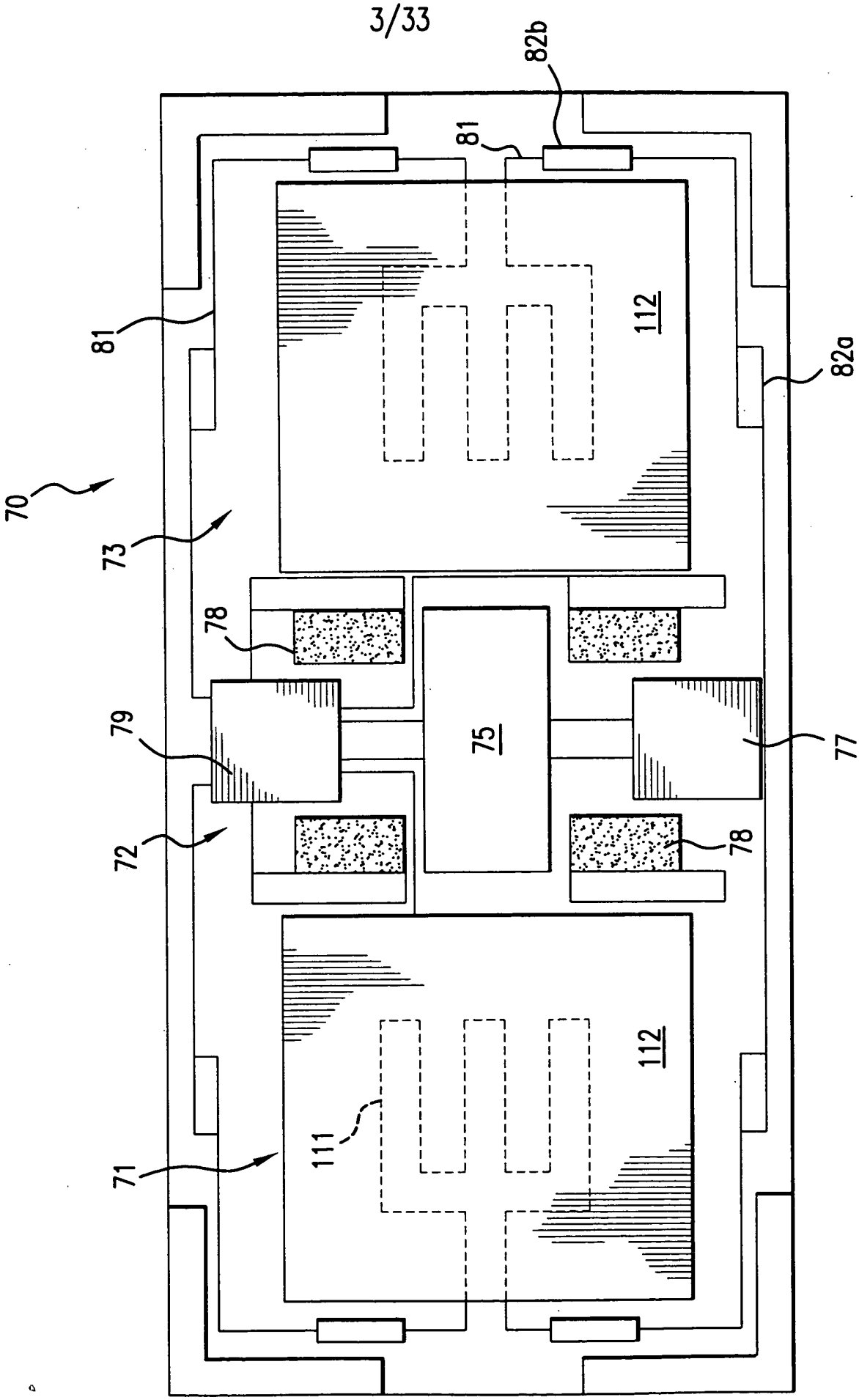


FIG.2C

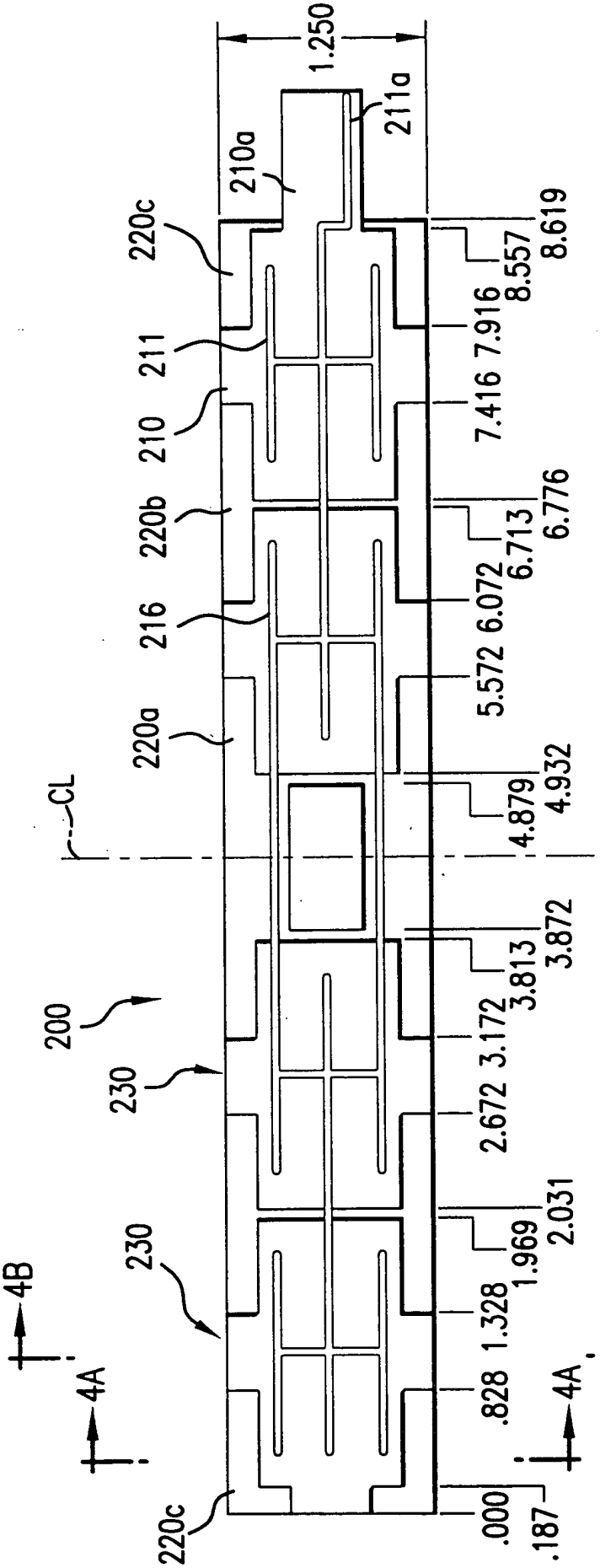

1.250
211a
210a
220c
211
210
220b
216
220a
CL
200
230
230
4B
4A
4A
4B
220c
.000
.187
.828
1.328
1.969
2.031
2.672
3.172
3.813
3.872
4.879
4.932
5.572
6.072
6.713
6.776
7.416
7.916
8.557
8.619

FIG.3

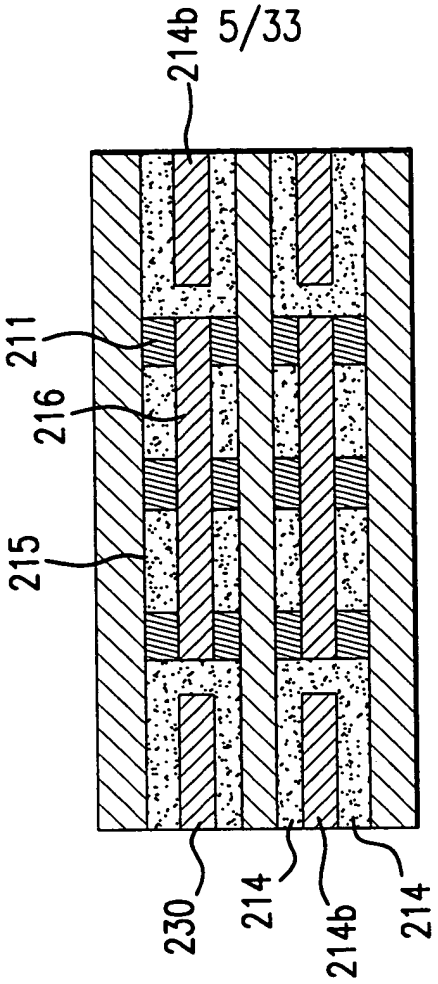

214b
211
216
215
230
214
214b
214

FIG.4B

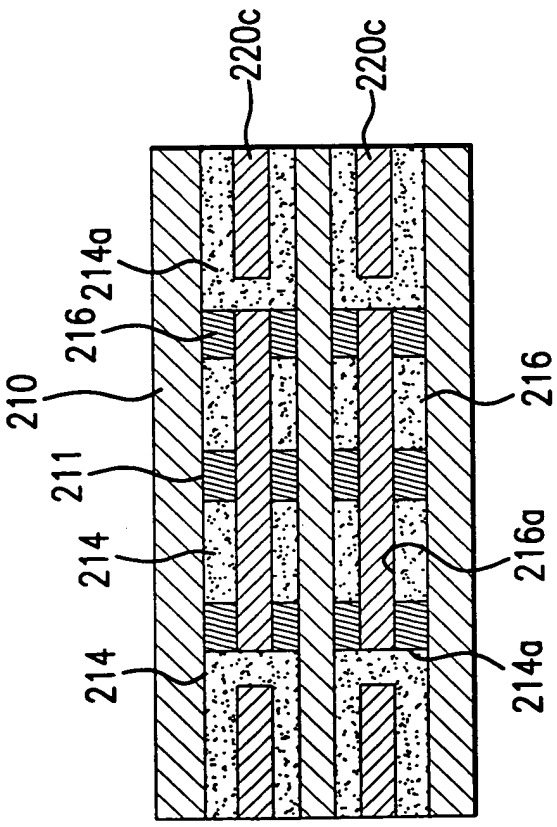

220c
220c
214a
216
210
216
211
214
216a
214
214a

FIG.4A

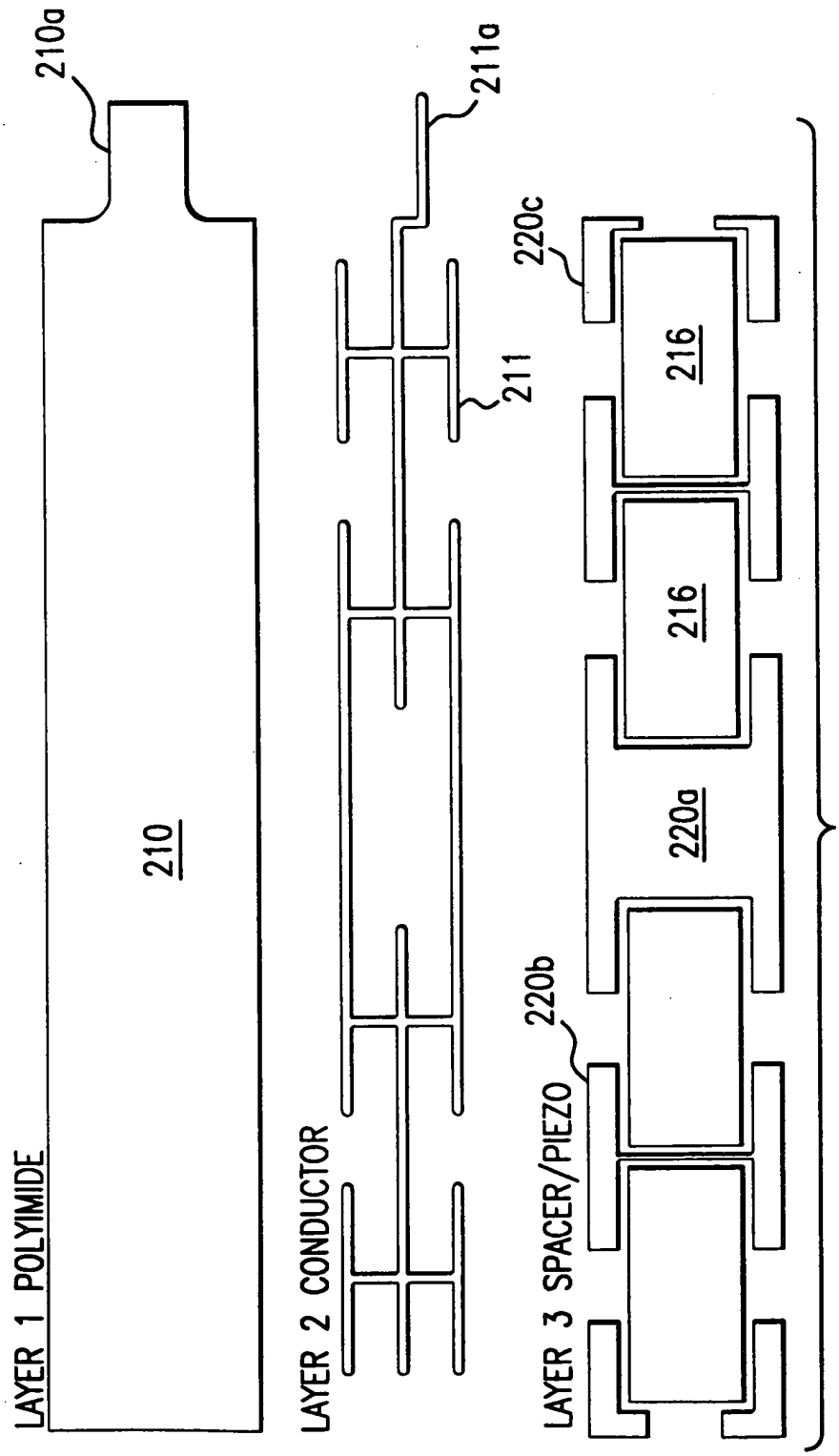

LAYER 1 POLYIMIDE
210
210a
LAYER 2 CONDUCTOR
211
211a
LAYER 3 SPACER/PIEZO
220a
220b
220c
216
216

FIG.5

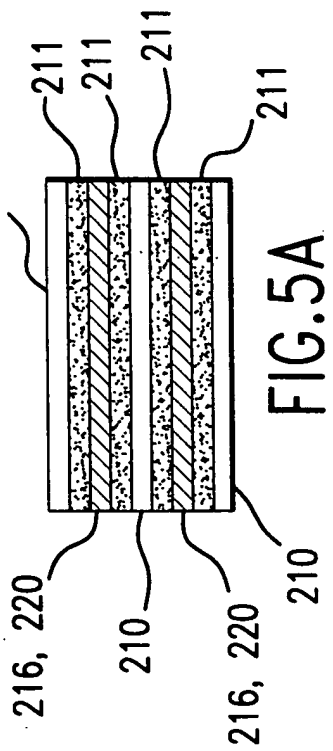

210
211
211
211
211
216, 220
210
216, 220
210

FIG.5A

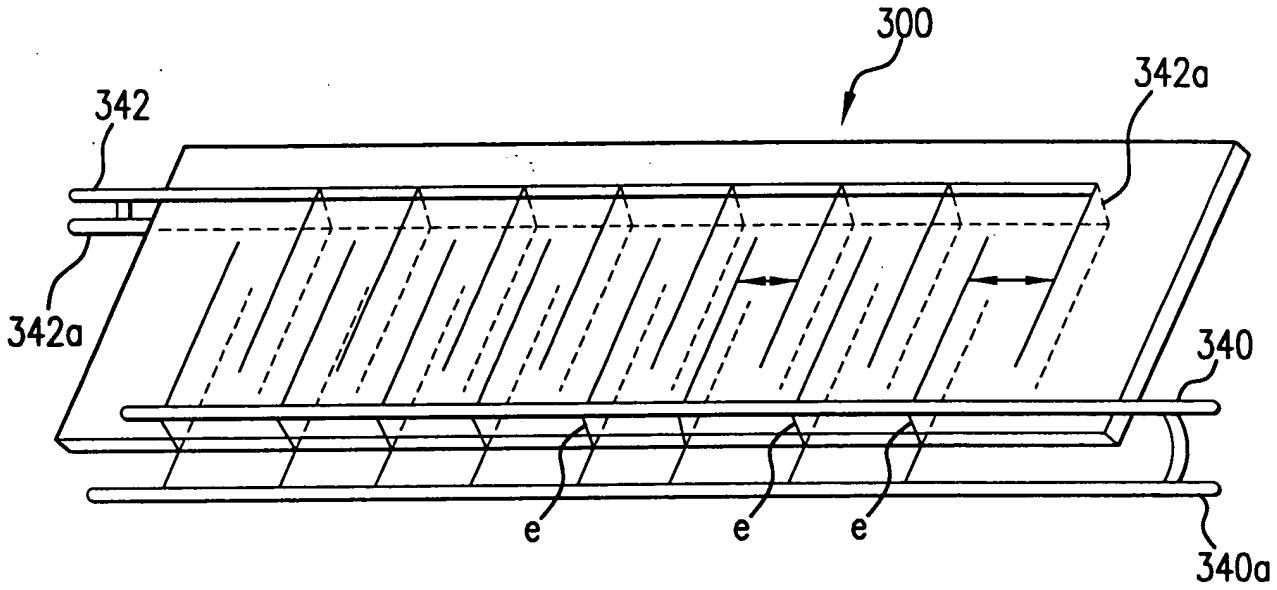


FIG.6

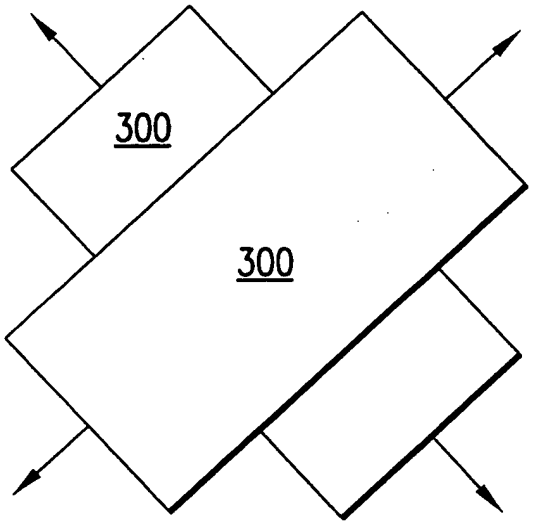


FIG.7

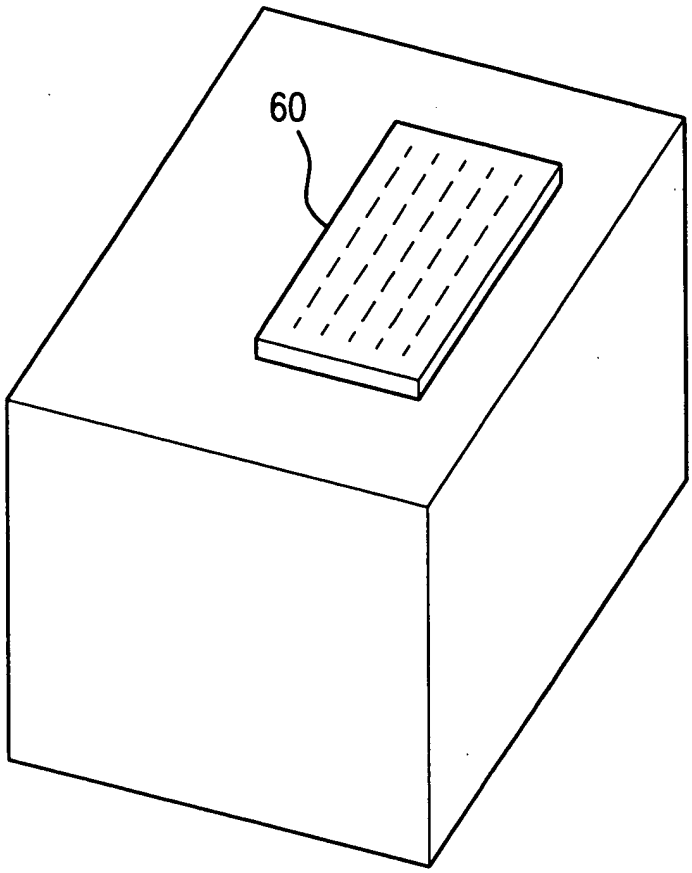


FIG.8A

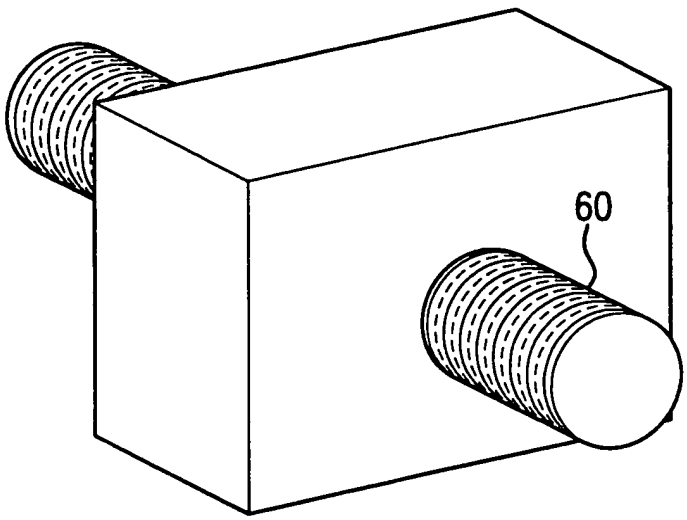


FIG.8B

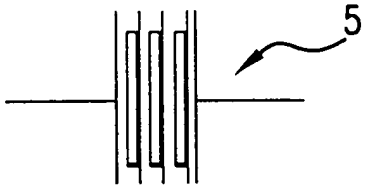


FIG.9A

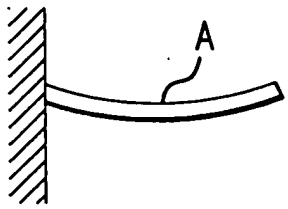


FIG.9B

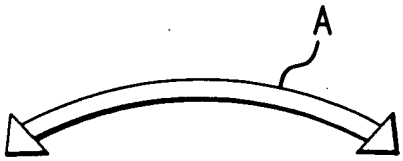


FIG.9C

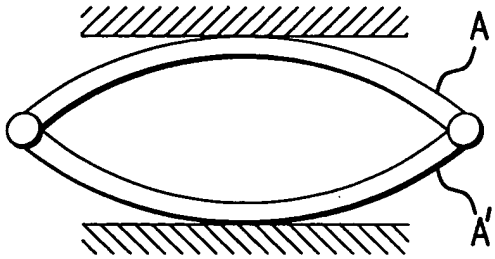


FIG.9D

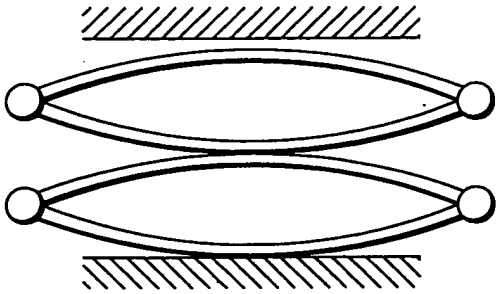


FIG.9E

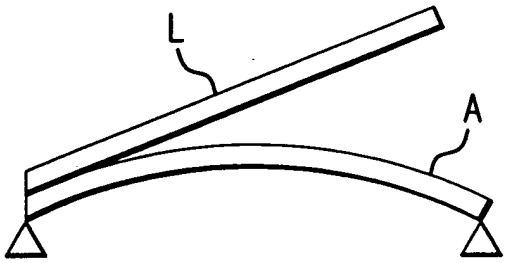


FIG.9F

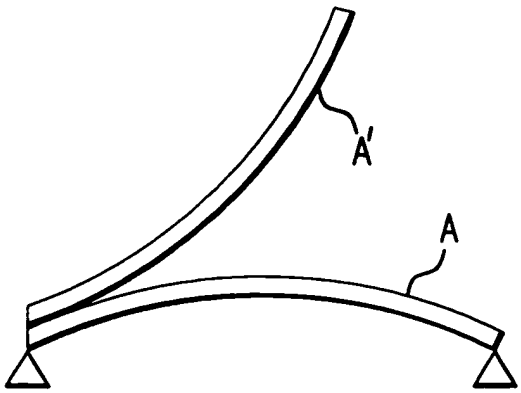


FIG.9G

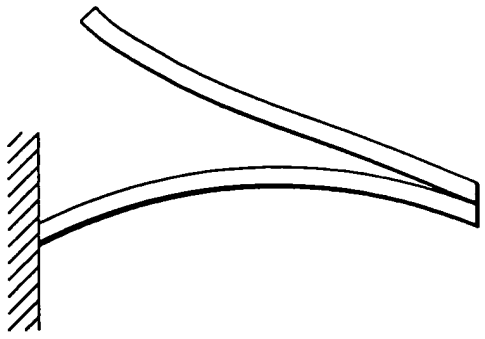


FIG.9H

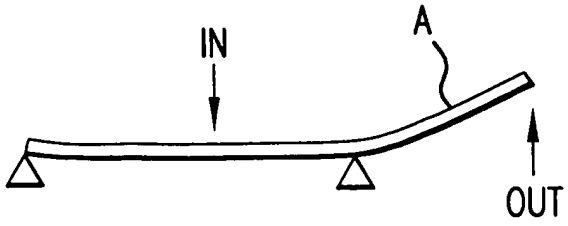


FIG.9I

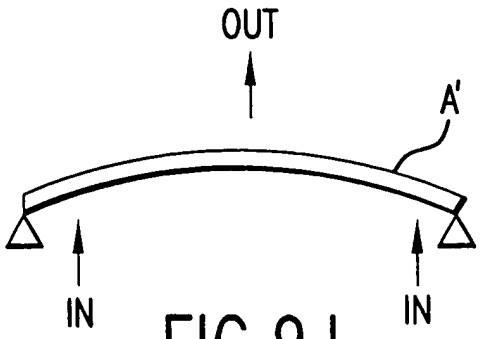


FIG.9J

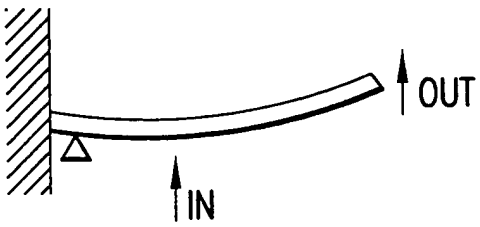


FIG.9K

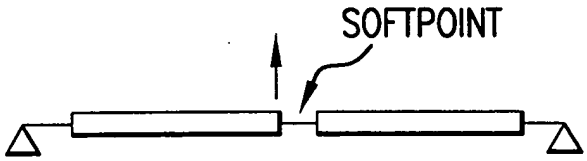


FIG.9L

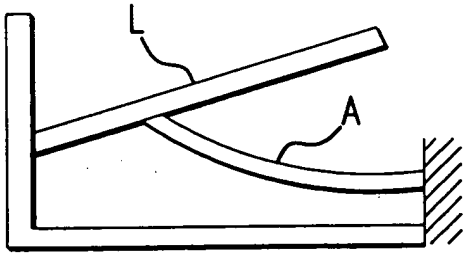


FIG.9M

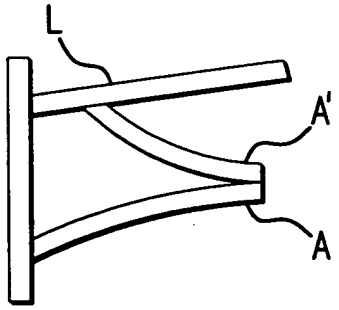


FIG.9N

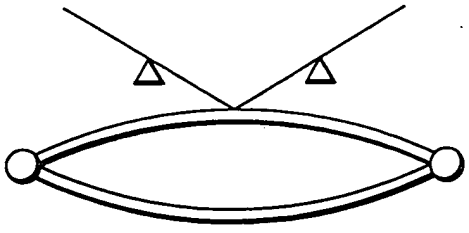


FIG.9O

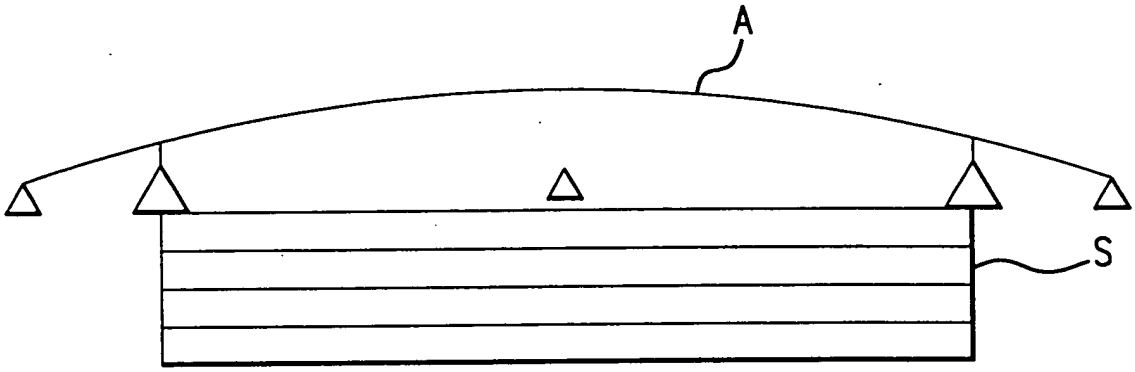


FIG.9P

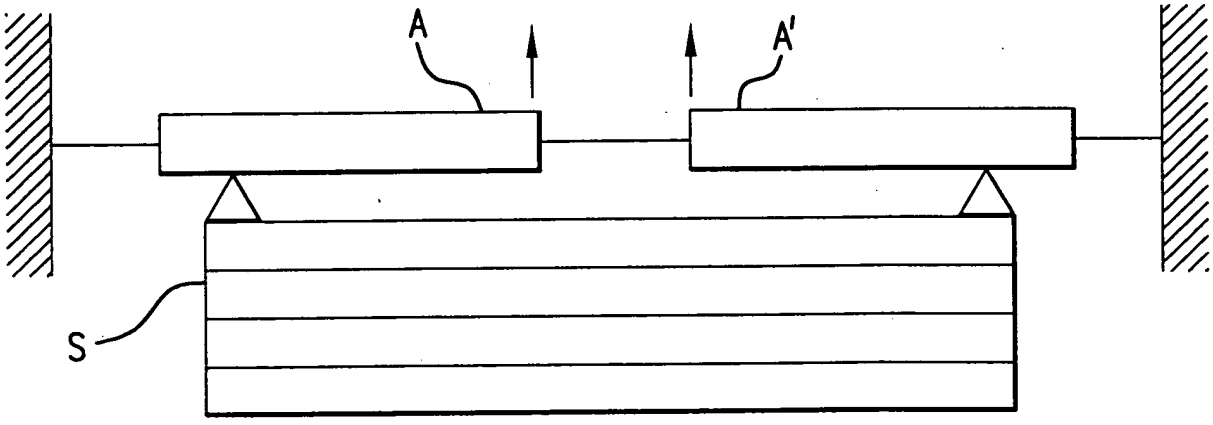


FIG.9Q

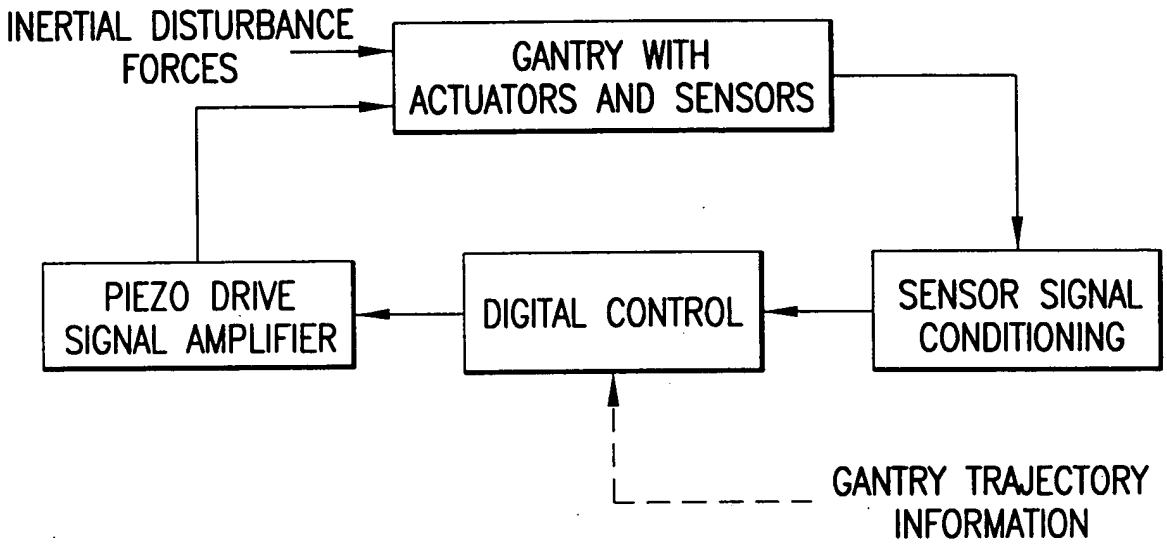

INERTIAL DISTURBANCE FORCES
GANTRY WITH ACTUATORS AND SENSORS
PIEZO DRIVE SIGNAL AMPLIFIER
DIGITAL CONTROL
SENSOR SIGNAL CONDITIONING
GANTRY TRAJECTORY INFORMATION

FIG.10

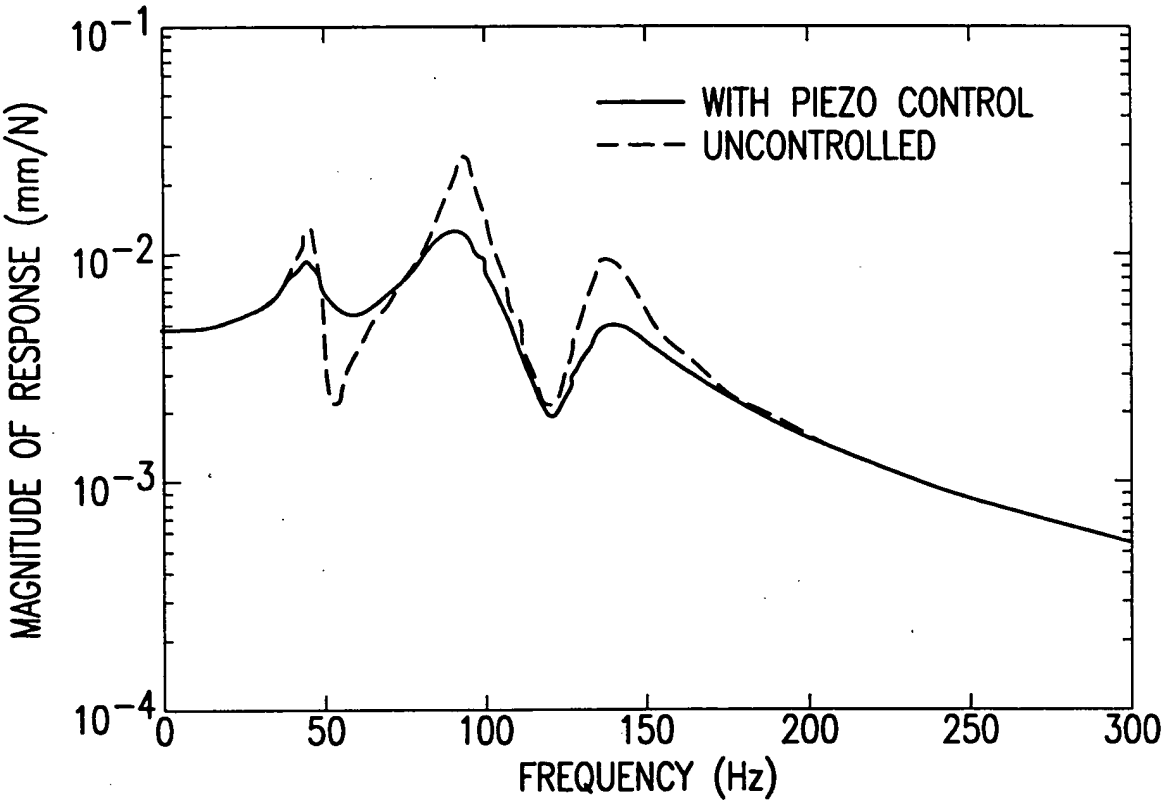

WITH PIEZO CONTROL
UNCONTROLLED
MAGNITUDE OF RESPONSE (mm/N)
FREQUENCY (Hz)
10^{-1}
10^{-2}
10^{-3}
10^{-4}
0
50
100
150
200
250
300

FIG.11

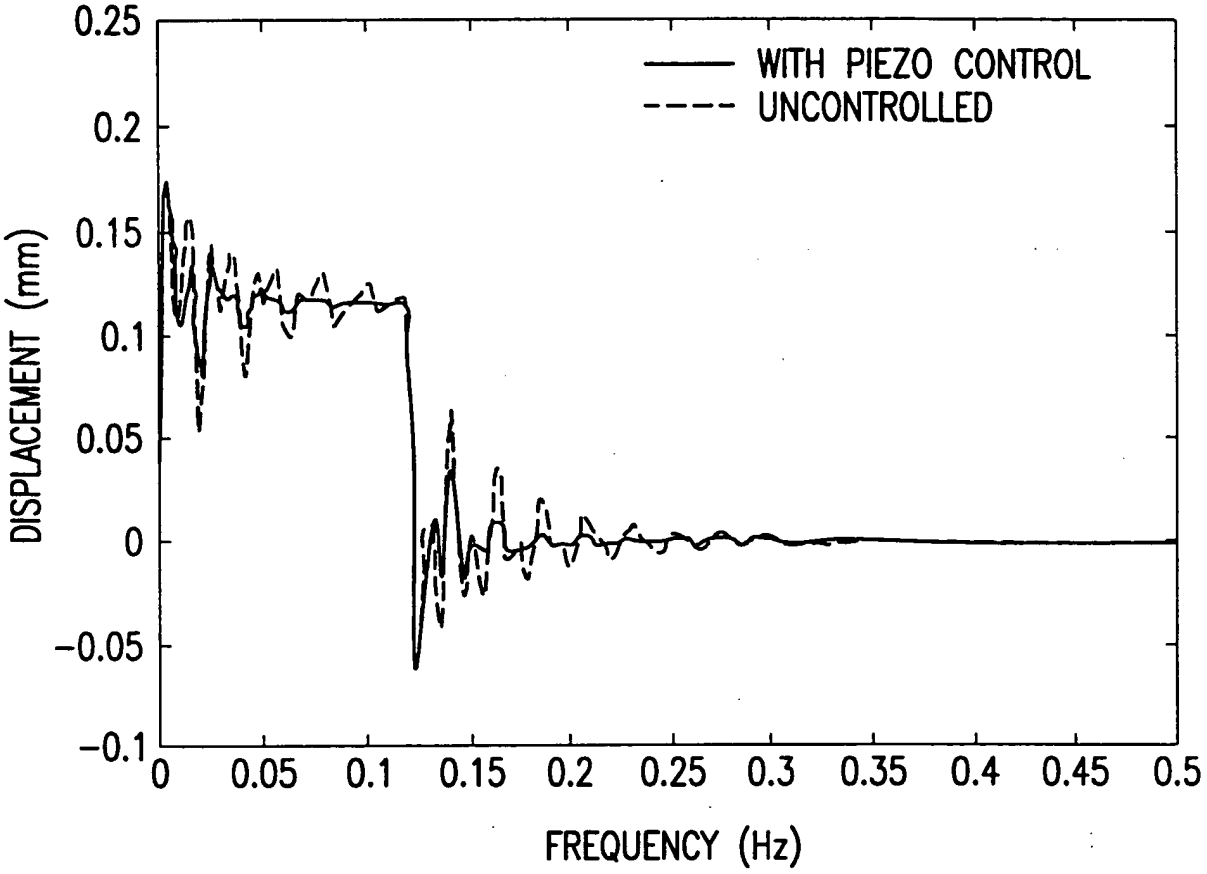

WITH PIEZO CONTROL
UNCONTROLLED
DISPLACEMENT (mm)
FREQUENCY (Hz)
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5

FIG.12

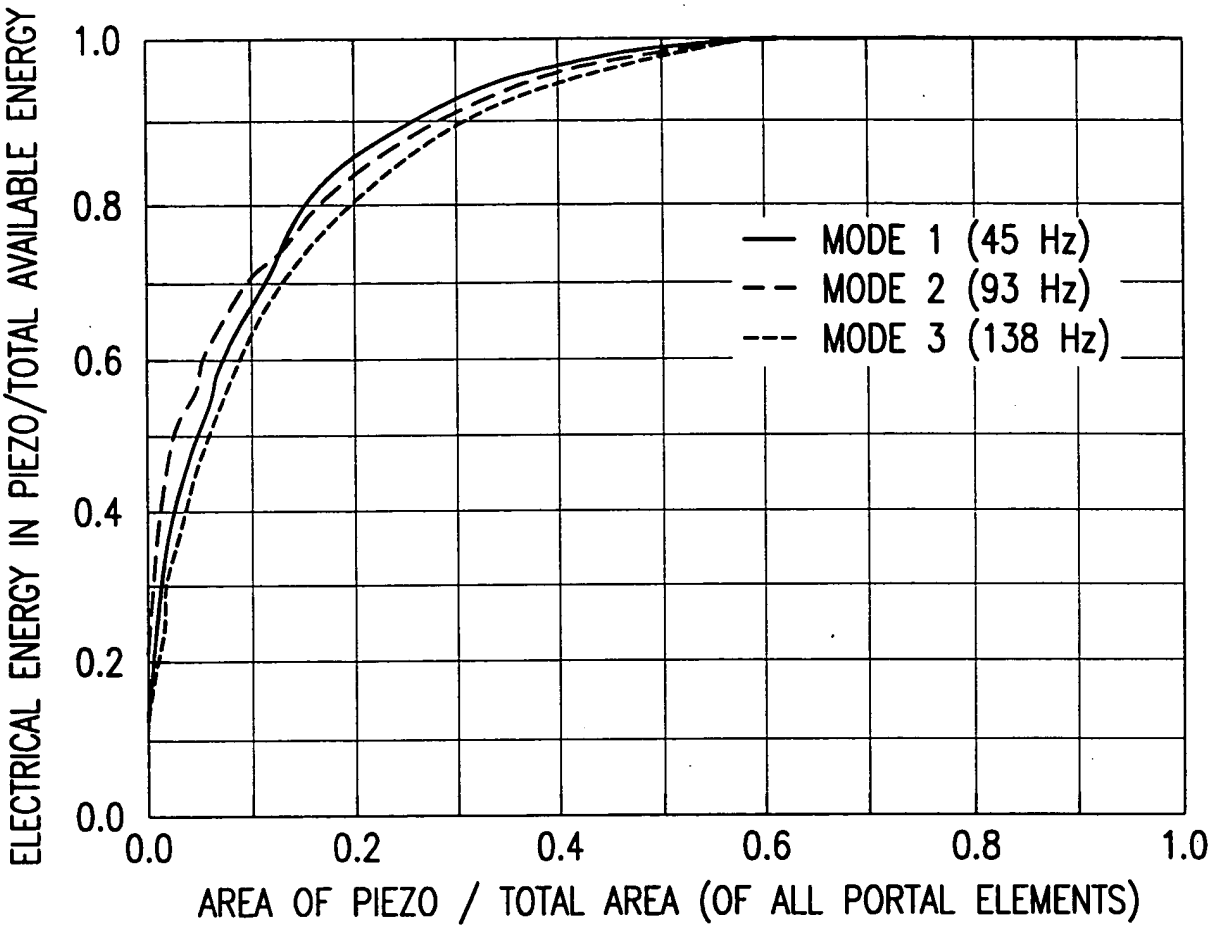

ELECTRICAL ENERGY IN PIEZO/TOTAL AVAILABLE ENERGY
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
AREA OF PIEZO / TOTAL AREA (OF ALL PORTAL ELEMENTS)
MODE 1 (45 Hz)
MODE 2 (93 Hz)
MODE 3 (138 Hz)

FIG.13

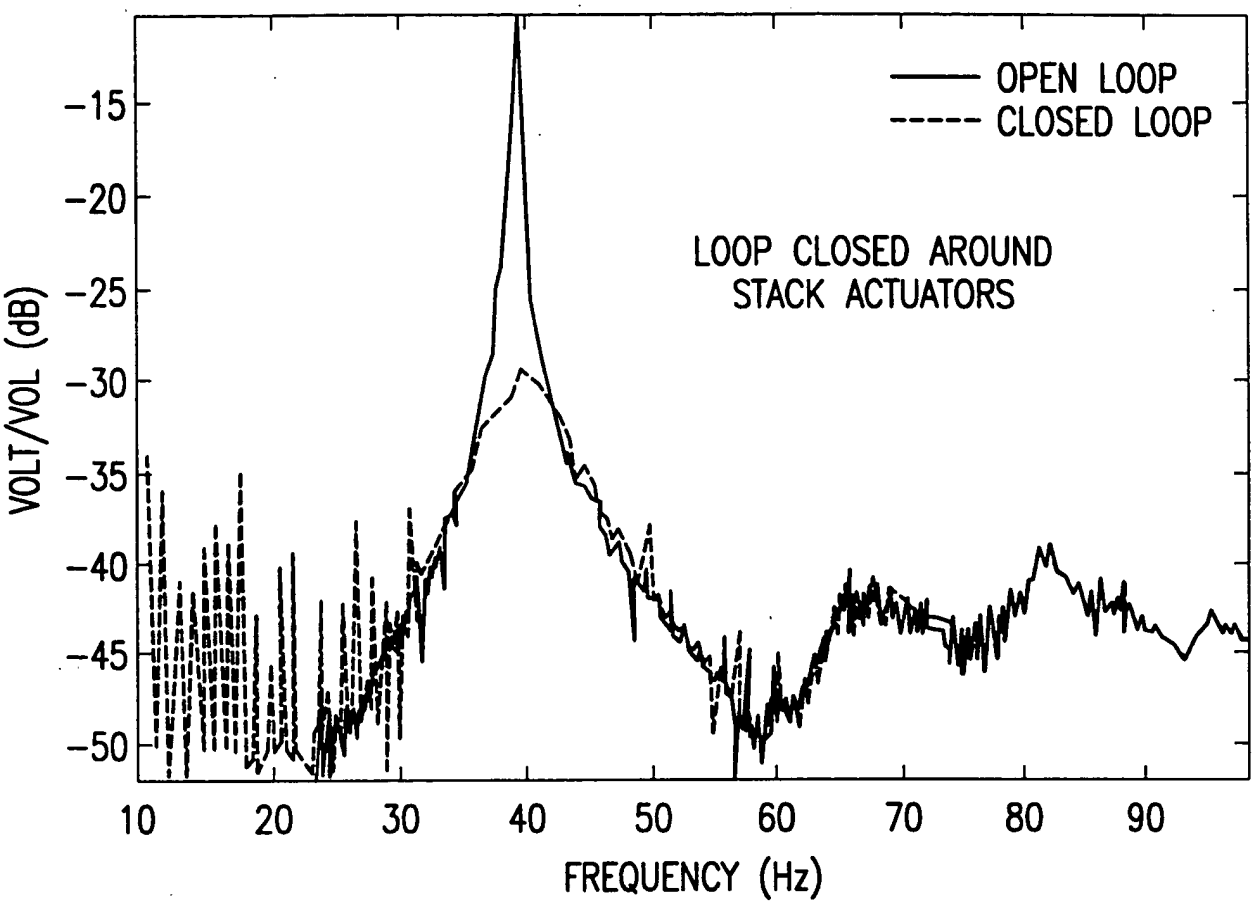

OPEN LOOP
CLOSED LOOP
LOOP CLOSED AROUND
STACK ACTUATORS
VOLT/VOL (dB)
-15
-20
-25
-30
-35
-40
-45
-50
10
20
30
40
50
60
70
80
90
FREQUENCY (Hz)

FIG.14

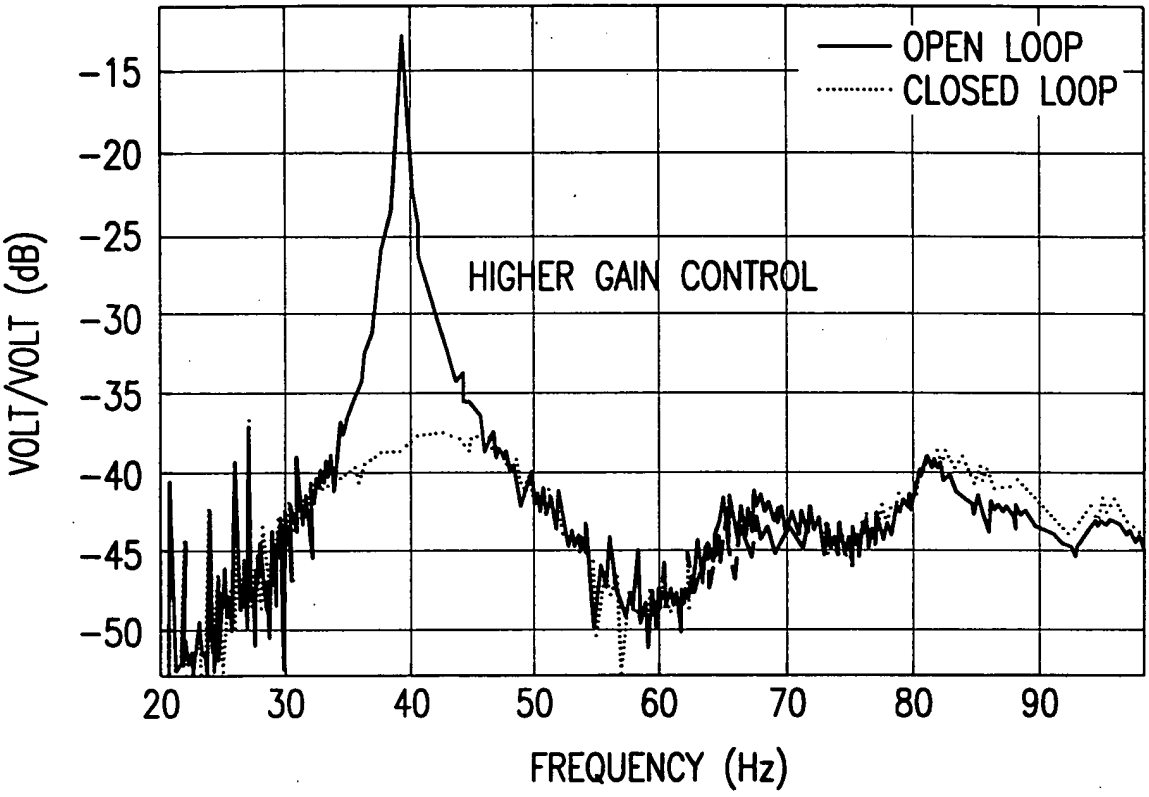

OPEN LOOP
CLOSED LOOP
HIGHER GAIN CONTROL
VOLT/VOLT (dB)
-15
-20
-25
-30
-35
-40
-45
-50
20
30
40
50
60
70
80
90
FREQUENCY (Hz)

FIG.15

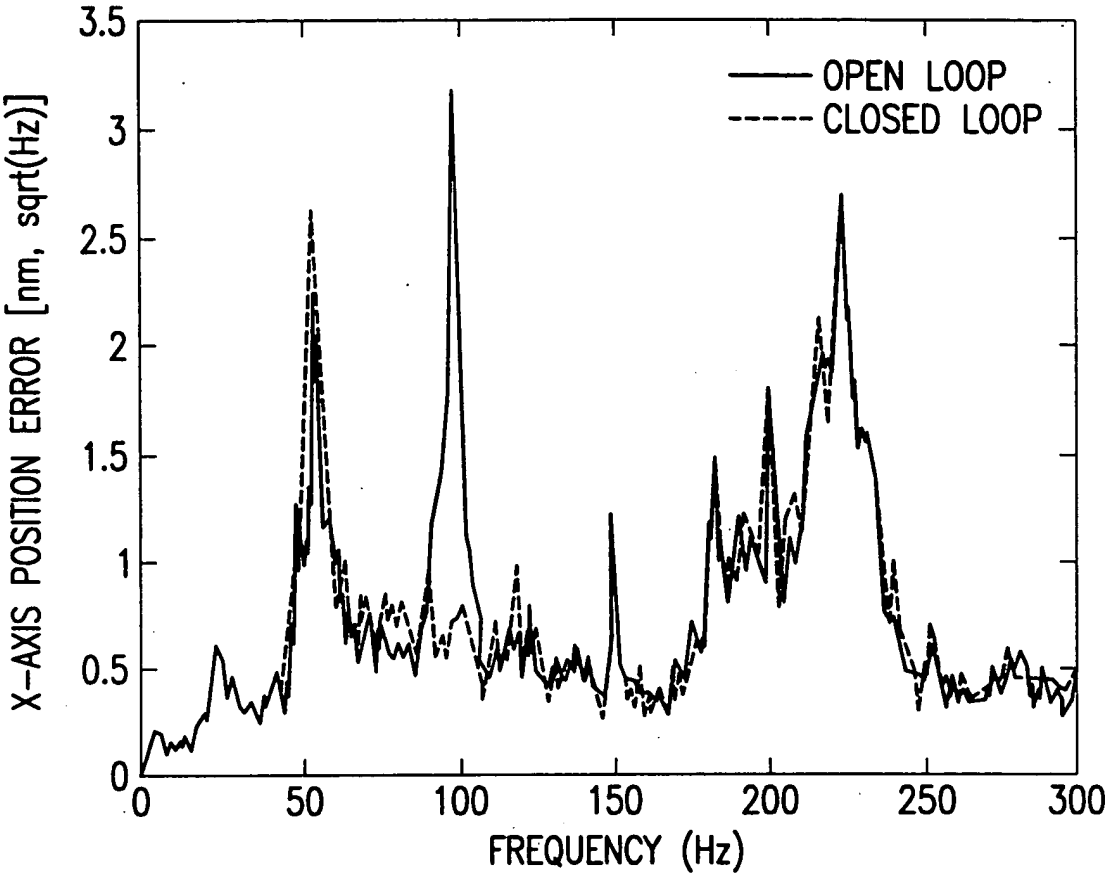

OPEN LOOP
CLOSED LOOP
X-AXIS POSITION ERROR [nm, sqrt(Hz)]
FREQUENCY (Hz)
0
0.5
1
1.5
2
2.5
3
3.5
0
50
100
150
200
250
300

FIG.16

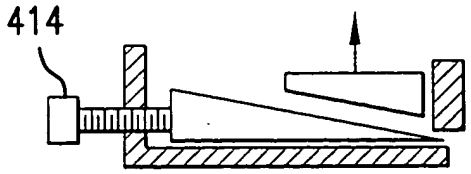


FIG.17

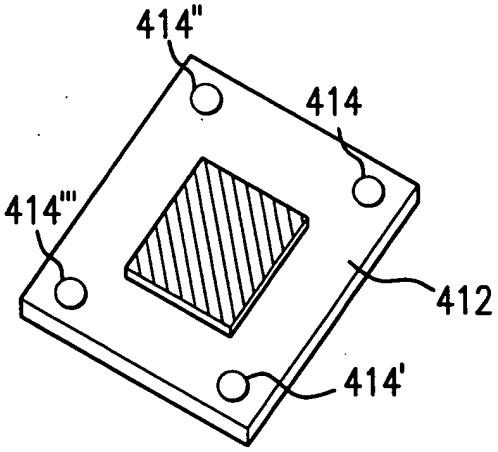


FIG.18

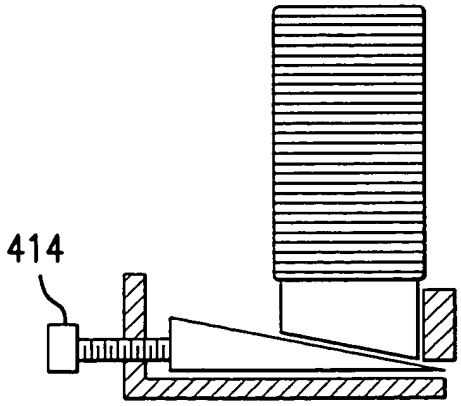


FIG.19

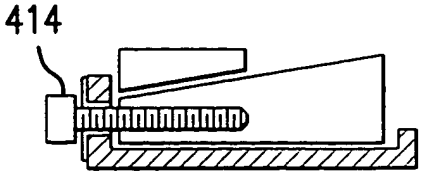


FIG.20

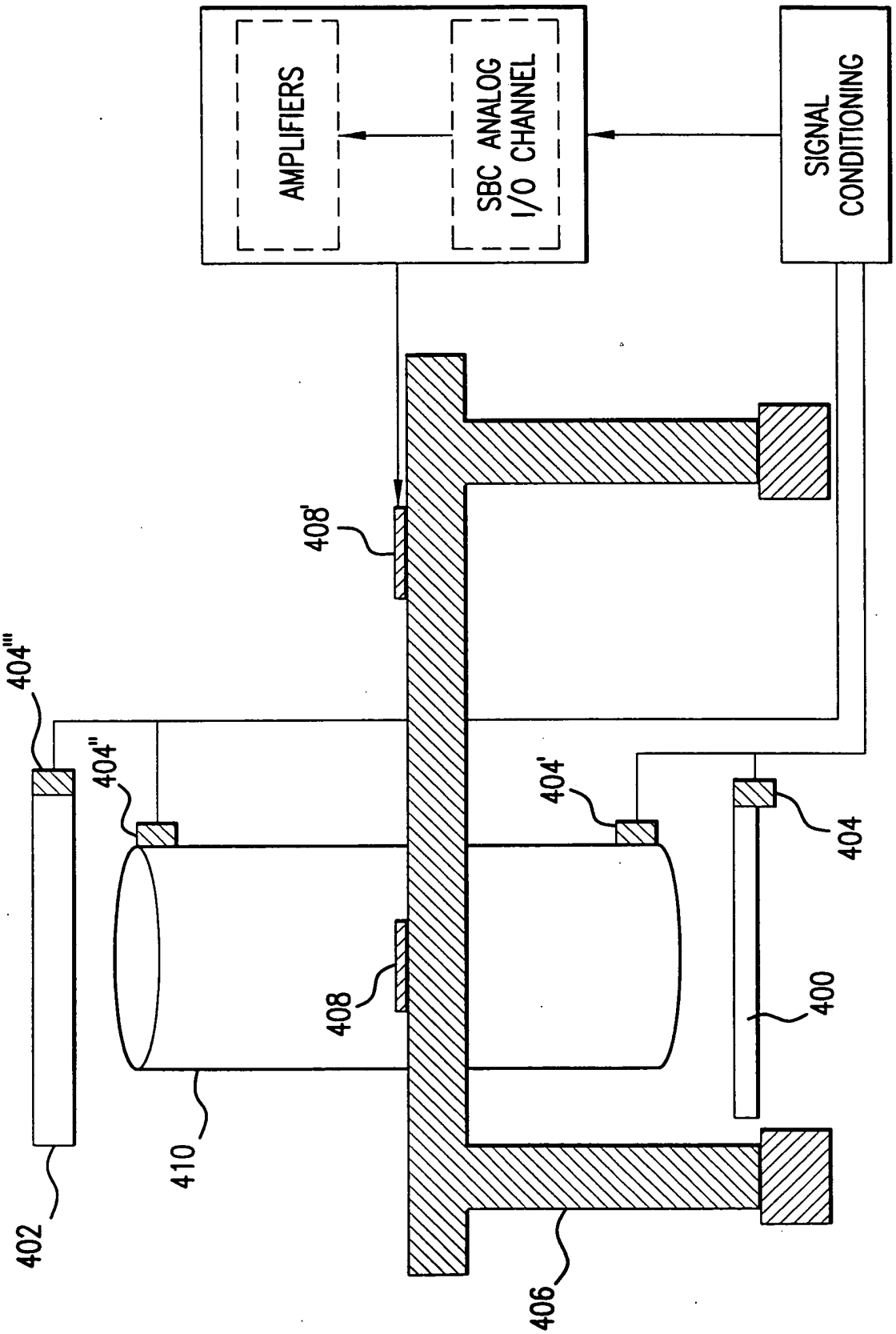
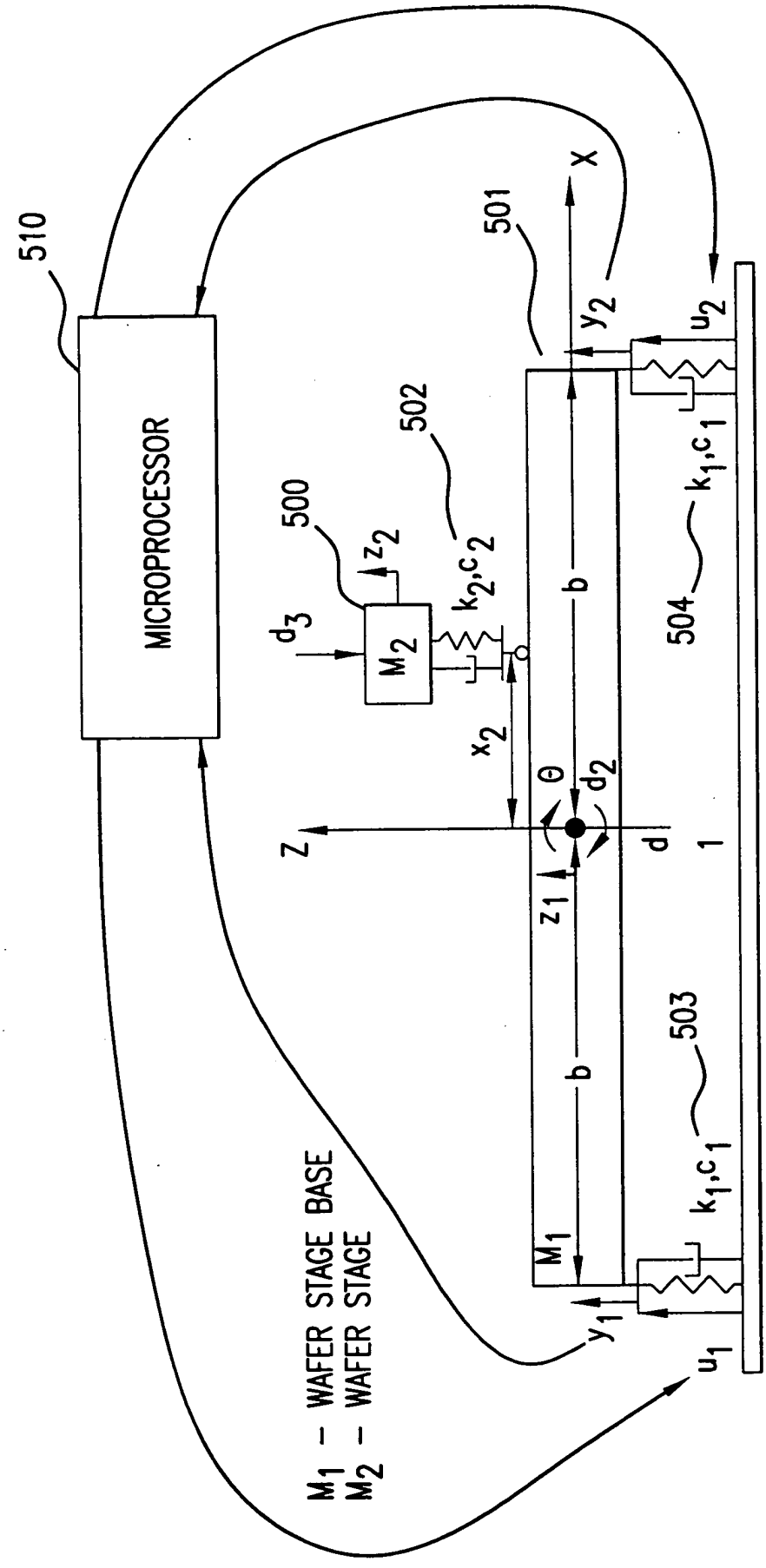

AMPLIFIERS
SBC ANALOG I/O CHANNEL
SIGNAL CONDITIONING
408'
404'''
404''
404'
404
408
400
410
402
406

FIG.21



- INPUTS (u_1): VOICE COIL FORCES ON BASE IN Z
- OUTPUTS (y_1): LASER DISPLACEMENT MEASUREMENTS COLLOCATED WITH VOICE COIL INPUTS
- DISTURBANCES (d_1): Z-FORCE AND θ MOMENT ON BASE, Z FORCE ON STAGE

FIG.22

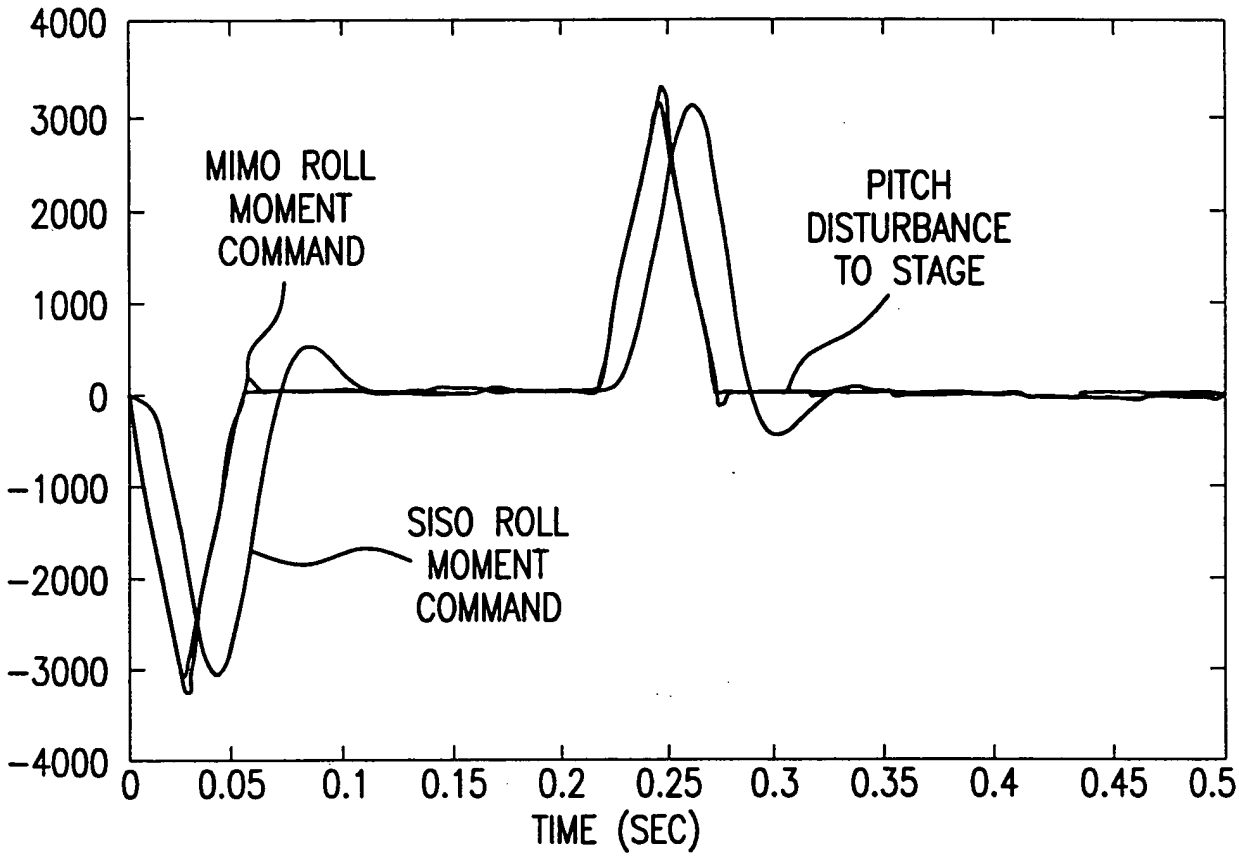

4000
3000
2000
1000
0
−1000
−2000
−3000
−4000
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
TIME (SEC)
MIMO ROLL MOMENT COMMAND
PITCH DISTURBANCE TO STAGE
SISO ROLL MOMENT COMMAND

FIG.23

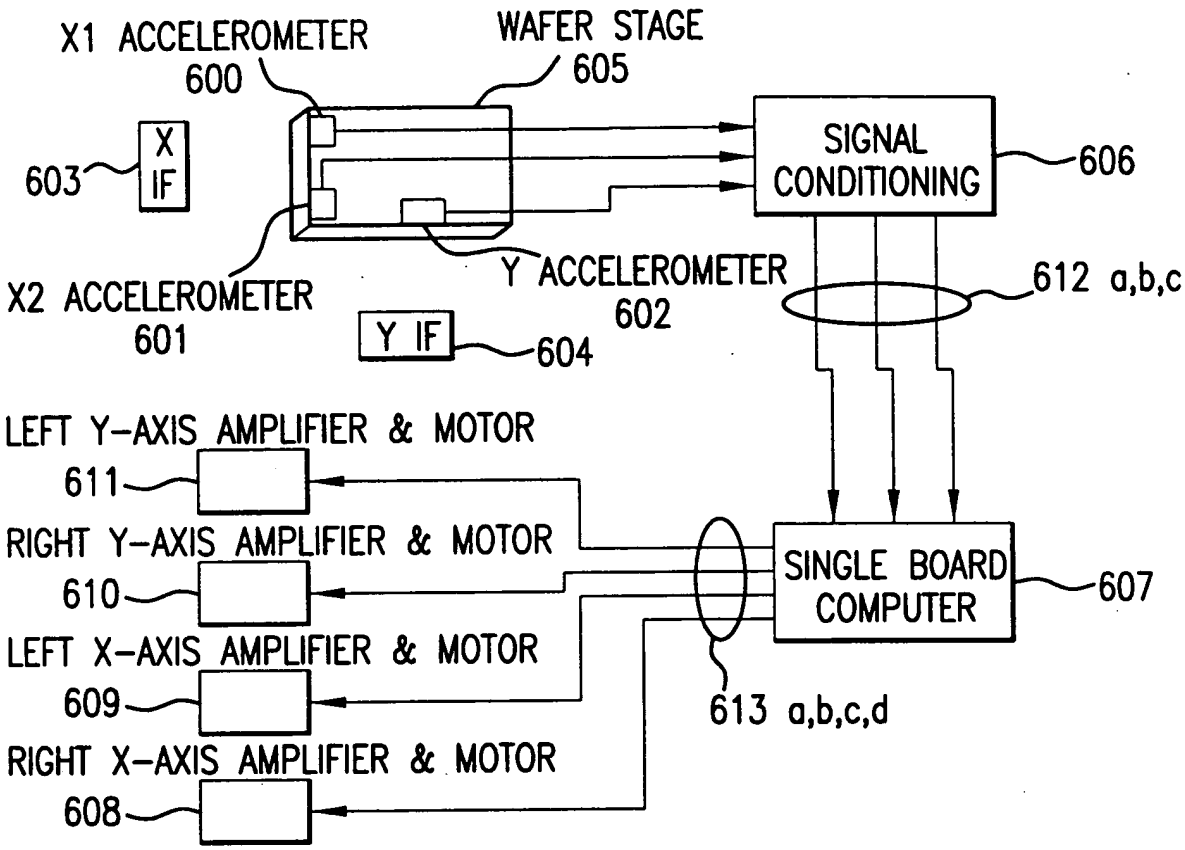

X1 ACCELEROMETER
600
WAFER STAGE
605
X
IF
603
SIGNAL
CONDITIONING
606
X2 ACCELEROMETER
601
Y ACCELEROMETER
602
612 a,b,c
Y IF
604
LEFT Y-AXIS AMPLIFIER & MOTOR
611
RIGHT Y-AXIS AMPLIFIER & MOTOR
610
LEFT X-AXIS AMPLIFIER & MOTOR
609
RIGHT X-AXIS AMPLIFIER & MOTOR
608
SINGLE BOARD
COMPUTER
607
613 a,b,c,d

FIG.24

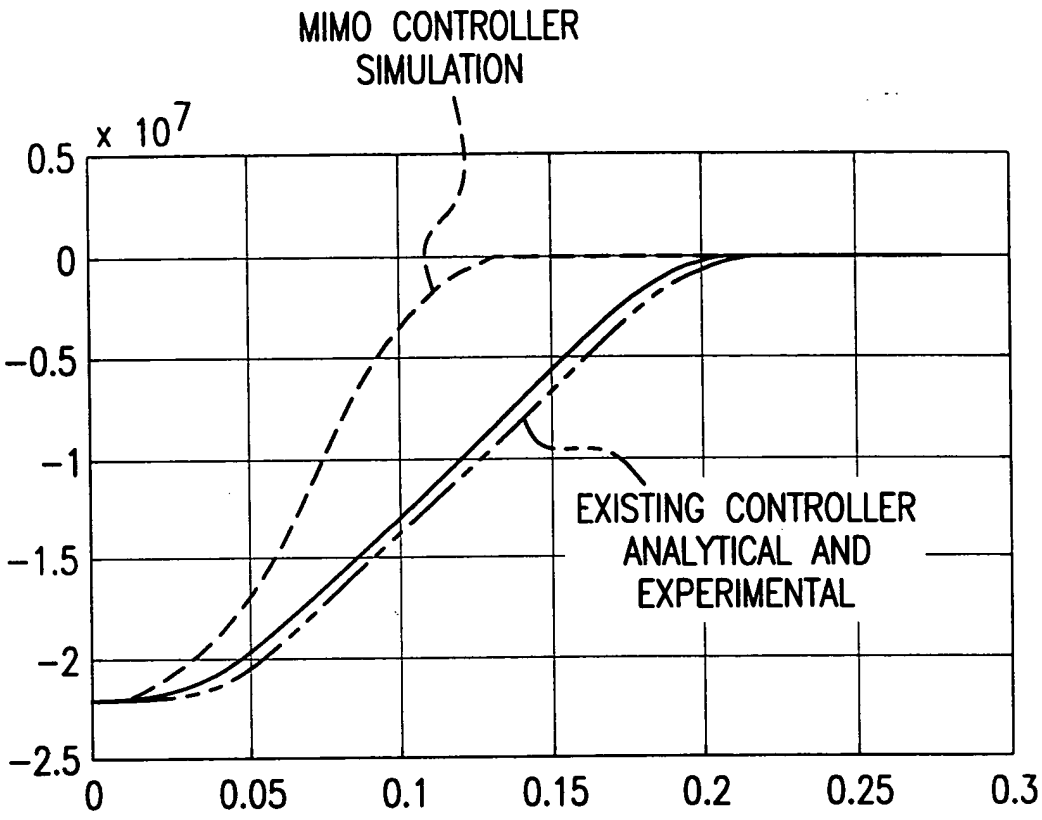

MIMO CONTROLLER
SIMULATION
x 10^7
0.5
0
-0.5
-1
-1.5
-2
-2.5
0
0.05
0.1
0.15
0.2
0.25
0.3
EXISTING CONTROLLER
ANALYTICAL AND
EXPERIMENTAL

FIG.25

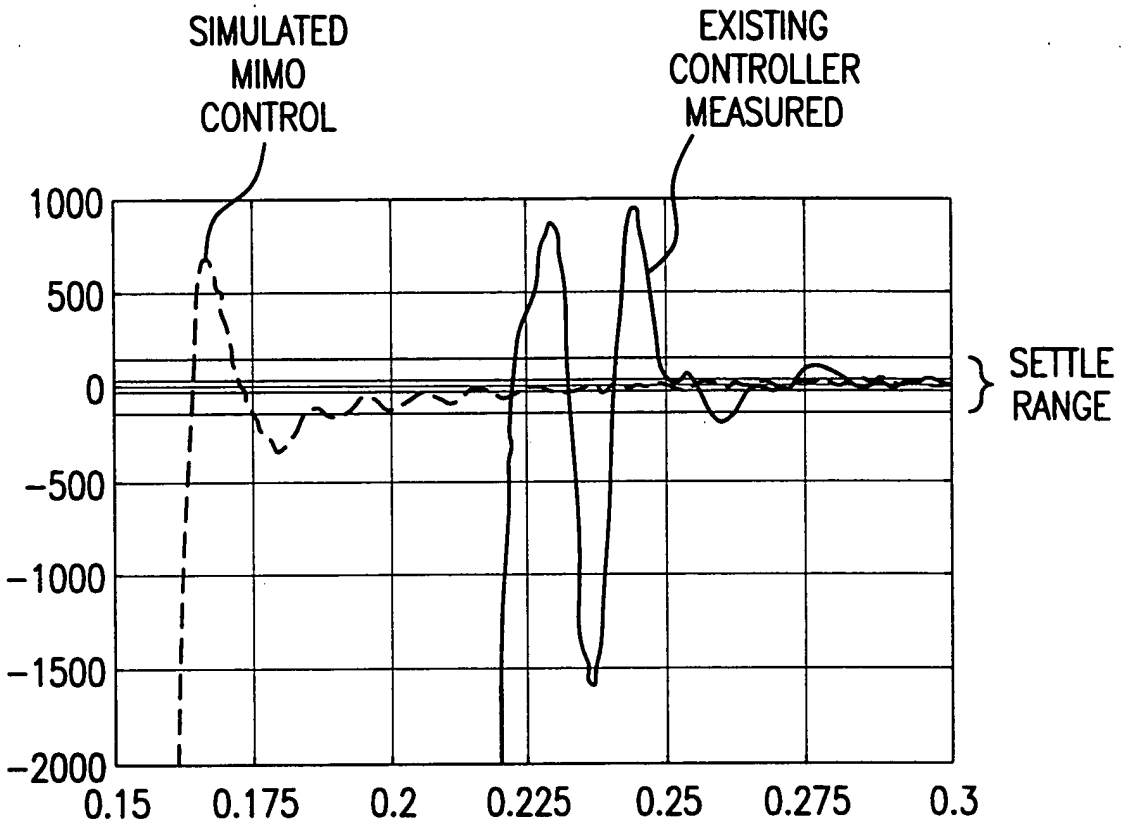

SIMULATED
MIMO
CONTROL
EXISTING
CONTROLLER
MEASURED
1000
500
0
-500
-1000
-1500
-2000
0.15
0.175
0.2
0.225
0.25
0.275
0.3
SETTLE
RANGE

FIG.26

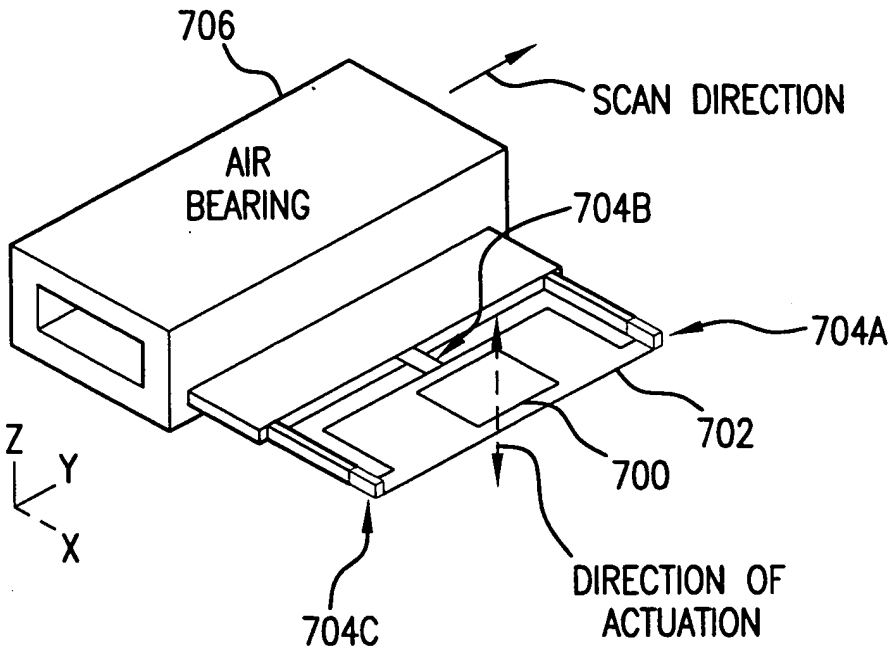

706
SCAN DIRECTION
AIR
BEARING
704B
704A
702
700
Z
Y
X
704C
DIRECTION OF
ACTUATION

FIG.27

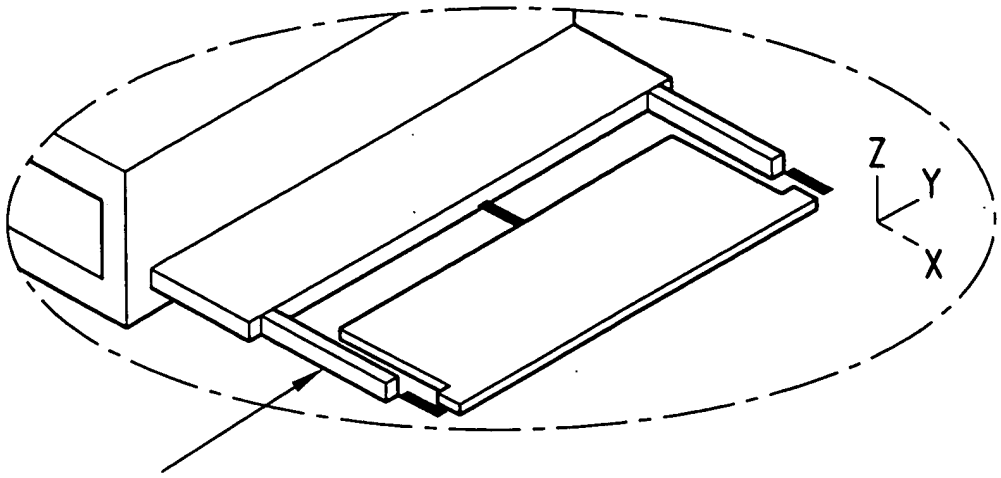


FIG.28A

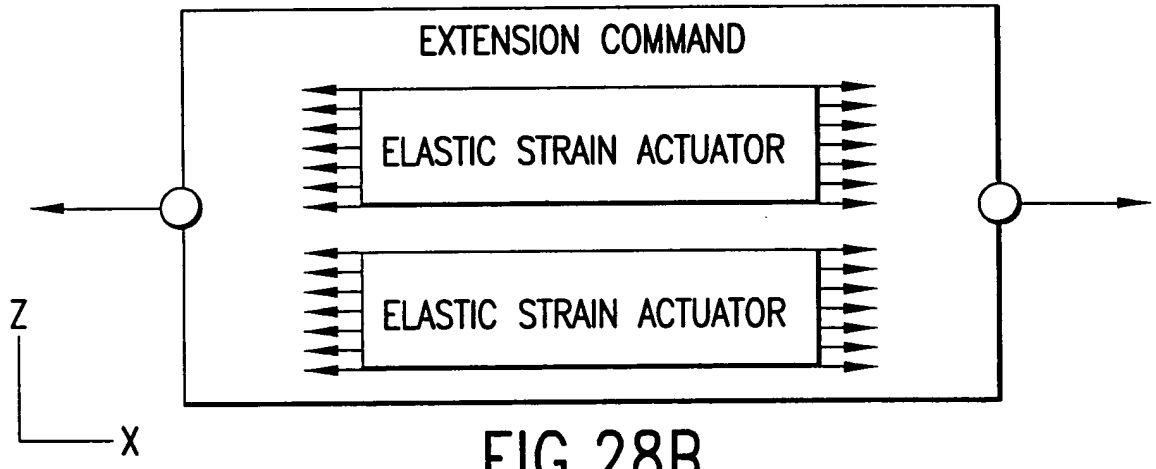


FIG.28B

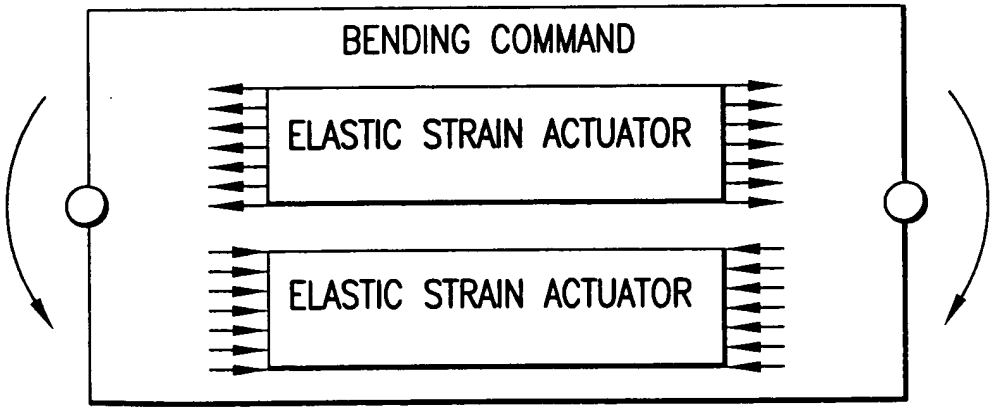


FIG.28C

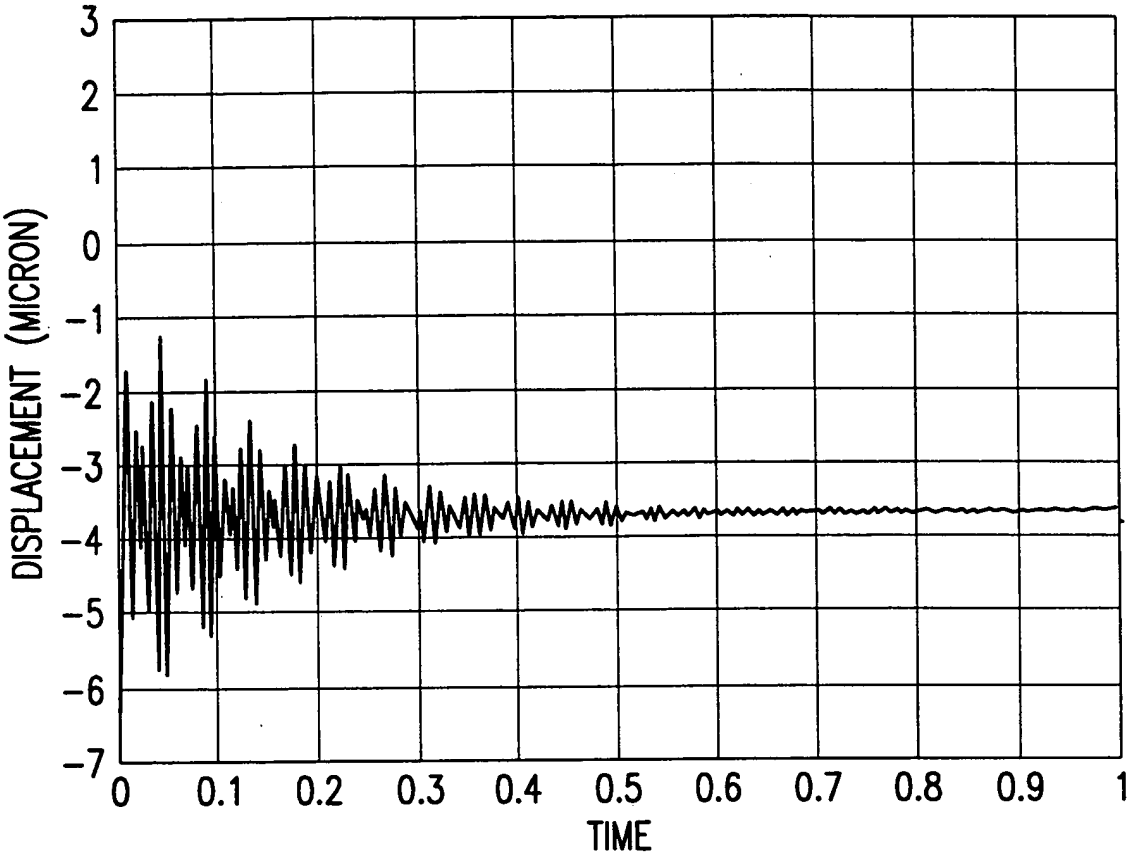


FIG.29A

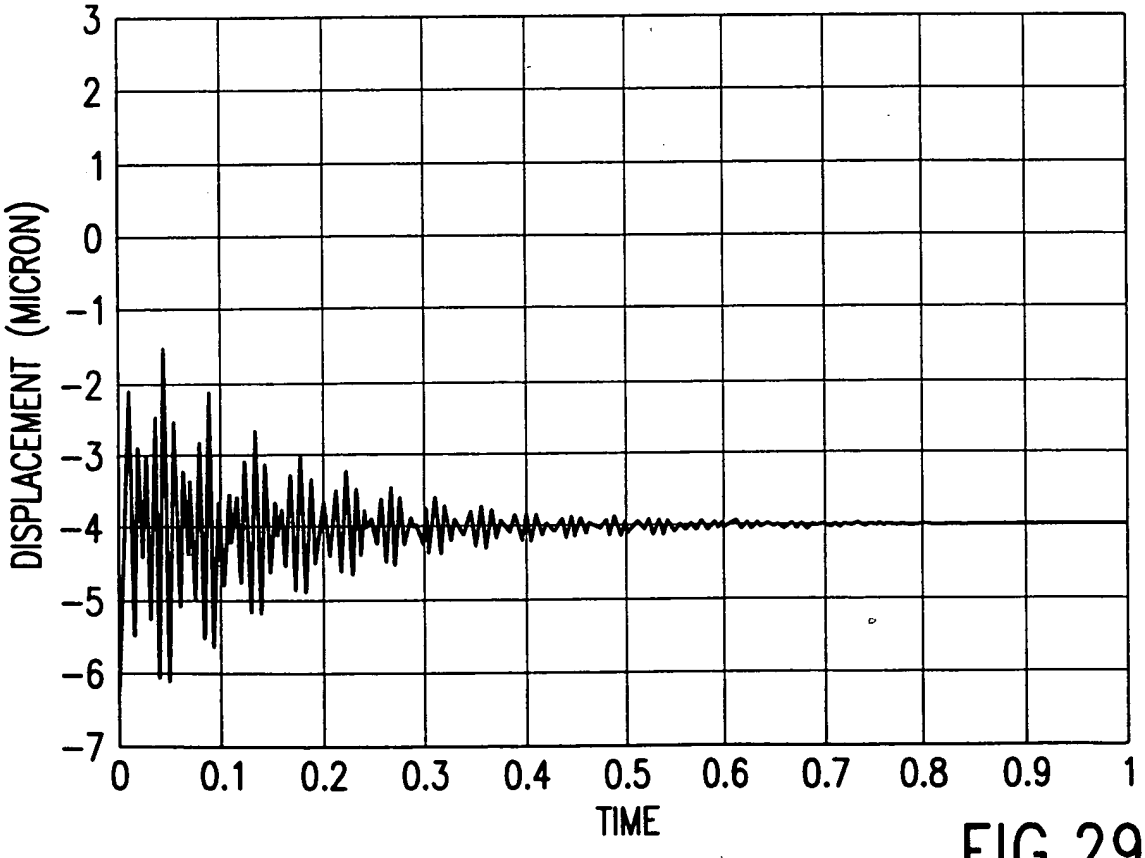


FIG.29B

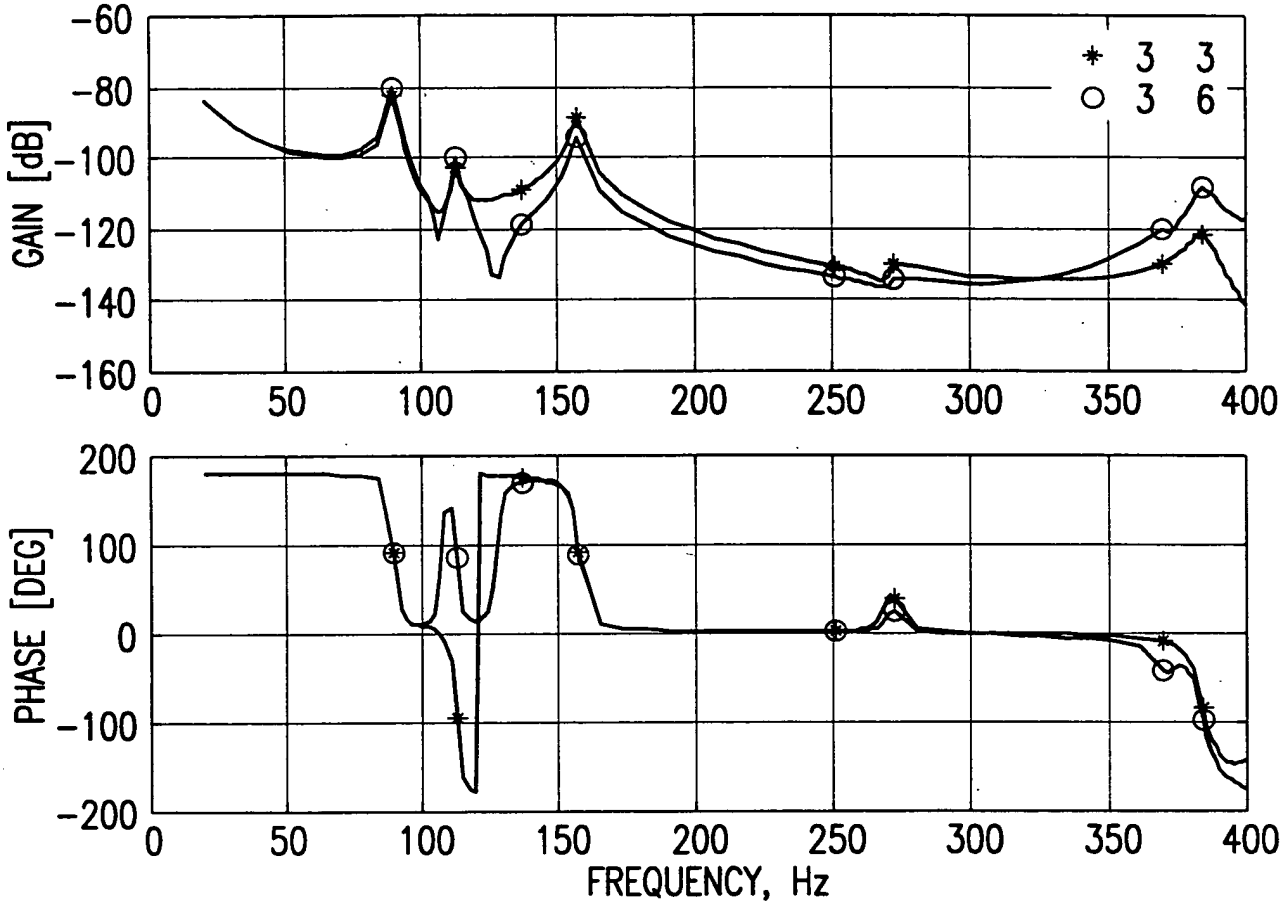

GAIN [dB]
-60
-80
-100
-120
-140
-160
0
50
100
150
200
250
300
350
400
3 3
3 6
PHASE [DEG]
200
100
0
-100
-200
FREQUENCY, Hz

FIG.30A

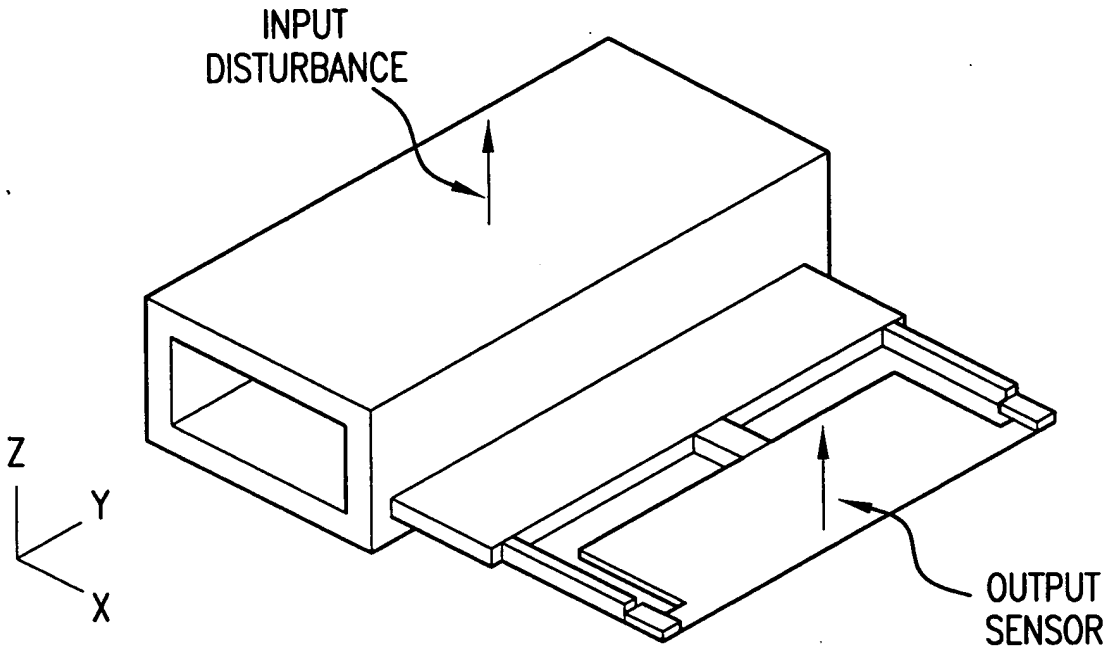


FIG.30B

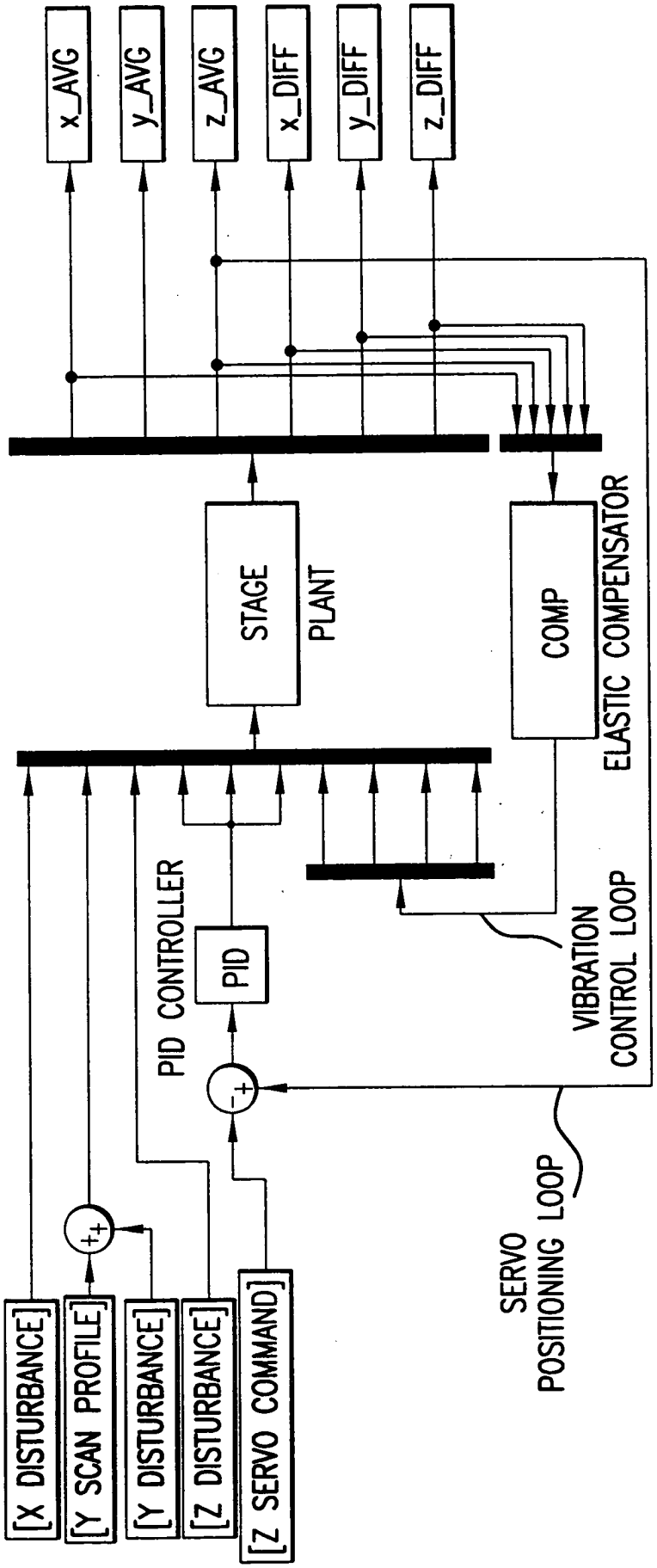

x_AVG
y_AVG
z_AVG
x_DIFF
y_DIFF
z_DIFF
STAGE
PLANT
COMP
ELASTIC COMPENSATOR
PID CONTROLLER
PID
VIBRATION
CONTROL LOOP
SERVO
POSITIONING LOOP
[X DISTURBANCE]
[Y SCAN PROFILE]
[Y DISTURBANCE]
[Z DISTURBANCE]
[Z SERVO COMMAND]

FIG.31

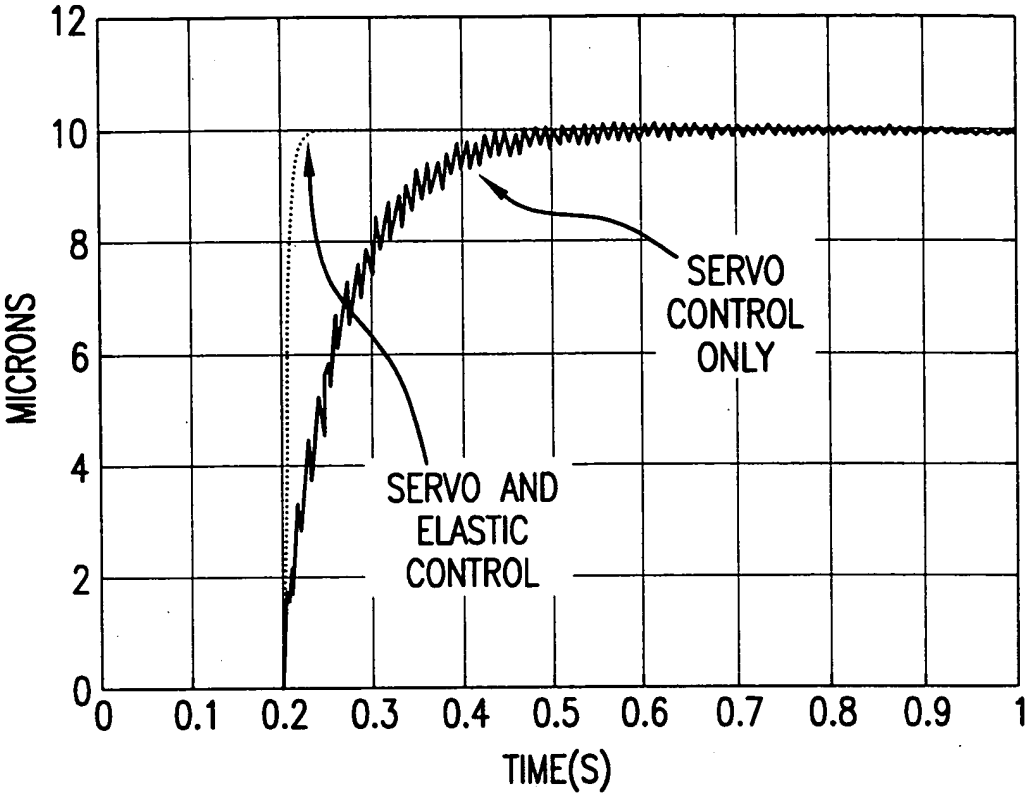

12
10
8
6
4
2
0
MICRONS
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
TIME(S)
SERVO CONTROL ONLY
SERVO AND ELASTIC CONTROL

FIG.32

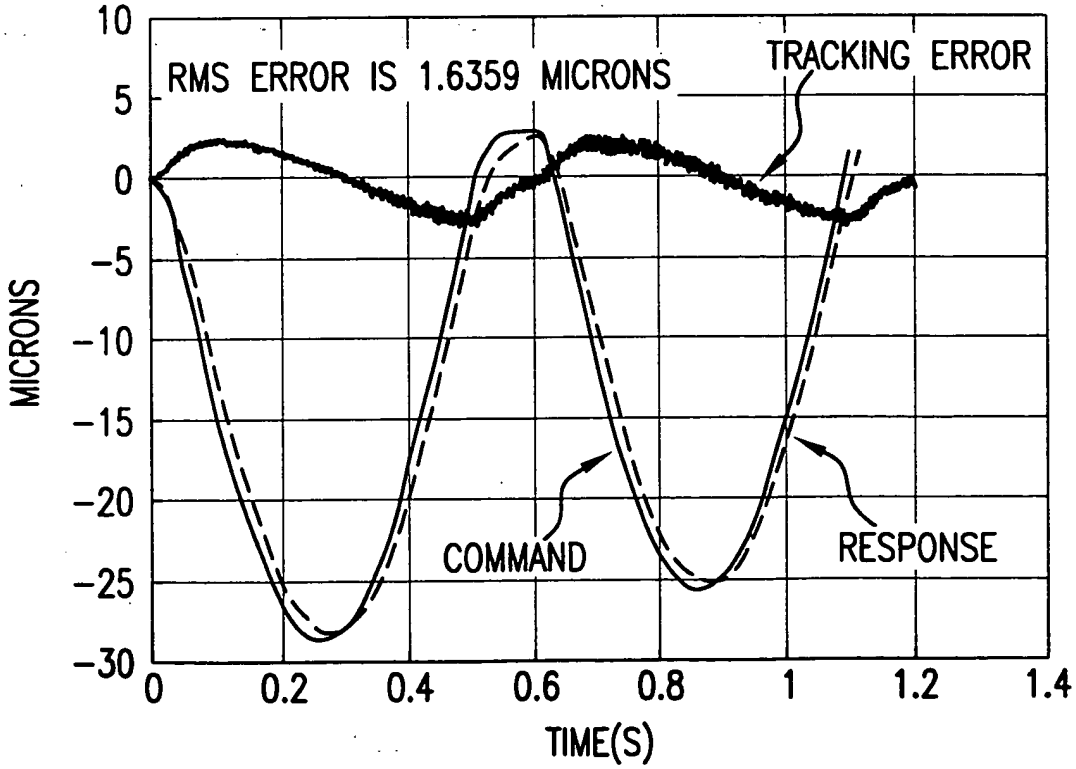

10
5
0
-5
-10
-15
-20
-25
-30
MICRONS
0
0.2
0.4
0.6
0.8
1
1.2
1.4
TIME(S)
RMS ERROR IS 1.6359 MICRONS
TRACKING ERROR
COMMAND
RESPONSE

FIG.33

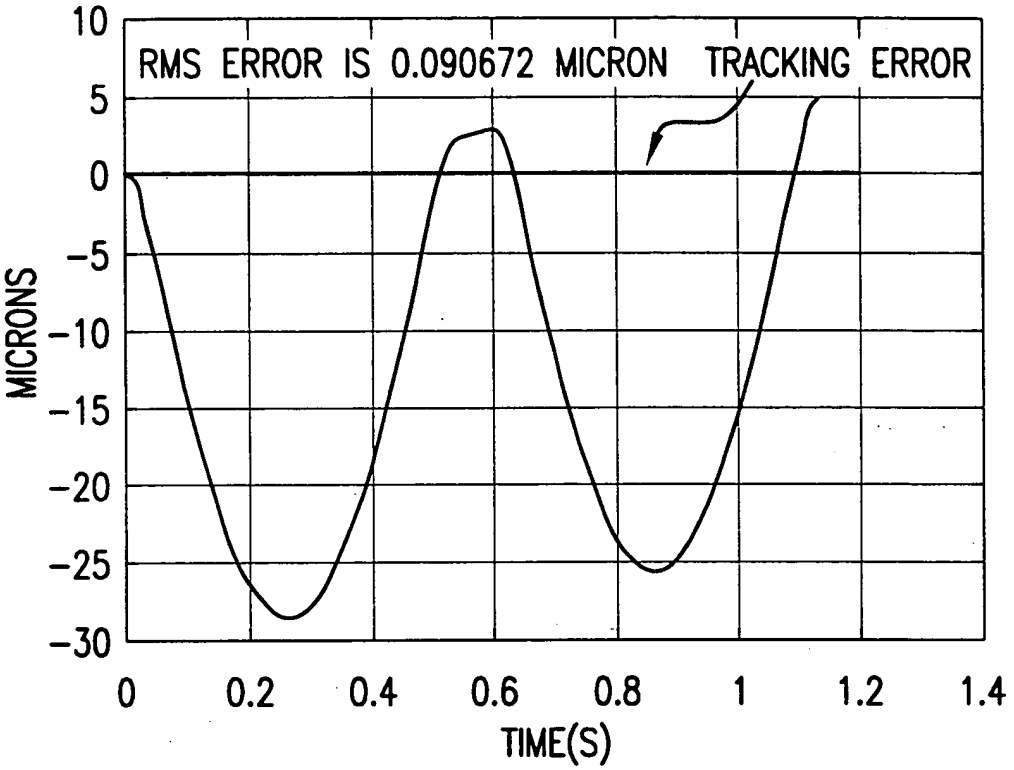

RMS ERROR IS 0.090672 MICRON TRACKING ERROR
10
5
0
-5
-10
-15
-20
-25
-30
MICRONS
0
0.2
0.4
0.6
0.8
1
1.2
1.4
TIME(S)

FIG.34